1987

Parameters of Peat Formation in the Mississippi Delta (Holocene).

Elisabeth Catharina Kosters
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PARAMETERS OF PEAT FORMATION IN THE MISSISSIPPI DELTA

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY OF THE
LOUISIANA STATE UNIVERSITY AND
AGRICULTURAL AND MECHANICAL COLLEGE
IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF
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IN

THE DEPARTMENT OF MARINE SCIENCES

BY

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M.S., UNIVERSITY OF AMSTERDAM, THE NETHERLANDS, 1982

May 1987

DEDICATION

This dissertation is dedicated to: Rob, Mara, Vader, Moeder, Nettie and Wim.

"I think I remember what Kant said: "understanding without observation is empty, but observation without understanding is dead". As long as one does not give names, one cannot observe what one sees. Maybe this is what makes our science so fascinating: one learns - a bit - to observe, and that is just about the most difficult thing to do"

Maarten 't Hart (Dutch ethologist and writer):
"De Waterstaafwants"

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represents compiled regression for all areas. Dot in circle on regression for area 3 represents two data points.

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ABSTRACT

The Mississippi Delta is located in a subtropical and moderately humid climate. Six major Holocene deltaic complexes developed, each with a life span of about 1500 years (Coleman and Gagliano, 1964; Frazier, 1967; Kolb and Van Lopik, 1958). Peats accumulate over abandoned delta lobes, in large-scale interdistributary basins, in abandoned channels, and as detrital peats nearshore. This dissertation discusses the first three types.

Emphasis is on Barataria Basin, a large-scale interdistributary basin, located between levees of the Lafourche and St. Bernard/Plaquemine delta complexes. A characteristic 6 m thick set of lithostratigraphic units constitutes basin-fill sediments. These units are: open bay, restricted basin, each blanketed by massive organic muds (abandonment phases), natural levee, basin drainage channel, lacustrine sediments, crevasses, and organic sediments, ranging from various types of organic-poor beds to organic-rich beds and peats. Organic-rich beds occur in three phases, each representing an accumulating period that was interrupted by subsidence and the influx of detrital clastics from renewed nearby fluvio-deltaic sedimentation.

Peats of the Mississippi Delta Plain accumulate in eutrophic, non-domed[1] environments in fresh water swamps and (often floating) marshes. Peats average 81.7% organic matter. They occur in the same stratigraphic unit as organic-rich beds and are predominately situated on top of clays and organic-poor sediment. In central Barataria Basin, peat beds are laterally discontinuous, contrasting with more continuous ones in the upper basin. This difference reflects greater subsidence and overbank flooding in the lower Basin compared to the upper basin. In the upper Basin, accumulation rates balanced with subsidence, whereas in the lower Basin, subsidence rates were higher, creating a depression that was prone to be flooded. Quantities of organic-rich material and peat are inversely related. In addition, quantities of peat and organic-poor material are inversely related. This latter correlation indicates either one of two possible settings:

1) more peat accumulated on top of organic-poor material, because organic-poor beds provided a base for plant growth and a supply of nutrients;
2) organic-poor material accumulated preferentially on top of peat because peat-accumulating areas eventually form topographic lows that were more likely to become flooded.

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[1] Cecil et al. (1985) distinguish eutrophic, non-domed (or planar) peats and domed (raised) oliogotrophic peats.

Relatively low mean organic matter content of peats in the Mississippi Delta is influenced by botanical parent material and short-term detrital clastic influx. Thickness and lateral continuity are restricted by subsidence and accretion, marine inundation and long-term effects of detrital clastic influx.

INTRODUCTION AND OBJECTIVES

Peat beds are important sedimentary deposits, because they represent a modern analogue of coal-forming environments and provide clues for reconstruction of geochronology. Peat has received little attention in literature dealing with deltaic environments. Most existing deltaic peat literature focuses on broad regional aspects of peat stratigraphy (Fisk, 1960; Coleman and Smith, 1964; Frazier, 1967; Frazier and Osanik, 1969) or on paleobotanical aspects and maceral types (Styan and Bustin, 1983, 1984; Cohen, 1973, 1974). Peat deposits of the Mississippi Delta were long considered prime examples of modern coal-forming environments (Wanless et al., 1963; Elliott, 1974b; Baganz et al., 1975; Horne et al., 1978; Ryer, 1981, Tewalt et al., 1981), although it had been shown that they contained very high ash percentages (Fisk, 1960; Frazier and Osanik, 1969). In addition, peaty (deltaic) deposits have experimentally been shown to be effective petroleum sources if reservoir development occurs geologically early (Rohrback et al., 1984; Risk and Rhodes, 1985, Shanmugan, 1985).

When studying deposits of modern environments, it is important to address fundamental questions regarding the relationships between sediments and the rock record. In the context of this study, the Mississippi Delta is evaluated an example of a modern coal-forming environment. Questions are

1) Can we explain the present situation?
2) Can we favorably compare the geometry of the delta lobes, their regional stratigraphy and local variation, the quality and quantity variations of the peats and associated deltaic strata to similar environments in the rock record?
3) If we do indeed see modern analogues of coal-forming environments in the Mississippi Delta, are these deposits likely to become preserved?

A problem one deals with when working in this area, is the historic aspect of research in the Mississippi Delta, one of the best studied in the world. The advantages of working in it are obvious: the literature has provided us with a well-constructed framework on which further studies can be anchored. However, there are disadvantages. The extrapolation of modern knowledge of the delta to the rock record is sometimes unclear. Literature dealing with the interpretation of depositional environments of coal often quotes Fisk's (1960) and Frazier's (1967) papers, without addressing the limitations of such comparisons. Also, such articles often compare ancient deposits to those of the modern Balize Delta (Elliott, 1974b, 1975). However, the Holocene deltas that constituted the deltaic plain reach maximum thicknesses of only about 20m, whereas the modern

Balize delta is up to 200 m thick (Coleman, 1981). Consequently, there are two types of environments that do not occur in the Balize delta: (1) abandoned deltas - (slowly) subsiding lobes upon which vegetation has developed, and (2) (large-scale) interdistributary basins (Coleman and Smith, 1964).

In many studies of deltaic lignites and coals (Kaiser, 1974, 1978; Kaiser et al., 1980; Horne et al., 1978; Flores, 1979) the authors have noted that the thickest coals are situated in close vicinity to clastic sediments that deposited more or less contemporaneously with peat formation. This situation is in contrast with the one proposed by Cecil et al. (1985), who suggested that a raised (ombrogenous) bog with complete absence of detrital clastic influx is required for low-ash peat accumulation. In addition, occurrences of thick coal seams in close proximity to detrital clastic sediments seems to contradict ideas put forward by many authors (Horne et al, 1978; Fisk, 1960; Frazier and Osanik, 1969) that high-quality peat forms in the center of basins away from detrital influx.

Researchers working in both ancient and modern sediments have so far not focused their investigations on quantified estimates of organic matter contents and detailed sedimentology simultaneously. Such information is needed to evaluate the potential of these deposits as coal precursors and to develop predictive models of coal formation. Thus, it is the objective of this study to provide a data base for evaluating quality, quantity, and lithofacies relationships of peats within the Holocene Mississippi Delta complex. In addition, I hope to create a framework from which comparisons to the rock record - with respect to deltaic coal-forming environments - can be properly made.

The four areas studied were: Gueydan, Avery Island, Lake Pontchartrain and Barataria Basin (Fig. 1). Research in Barataria Basin provides most of the data for this investigation. The three smaller areas, Gueydan (channel-fill peat), Avery Island (blanket peat), and Lake Pontchartrain (marginal deltaic plain) provided additional insight into peat formation.

The data base in all areas was formed by a collection of 7.5-cm-diameter vibracores, which were visually logged and occasionally analyzed using X-Ray radiography. In addition, lithology, degree of peat decomposition and broad botanical constituents were also noted. In analyzing X-ray radiographs, rooting and diagenetic features in peats and other organic beds were emphasized. A total of 789 samples was analyzed for both moisture and organic matter content.

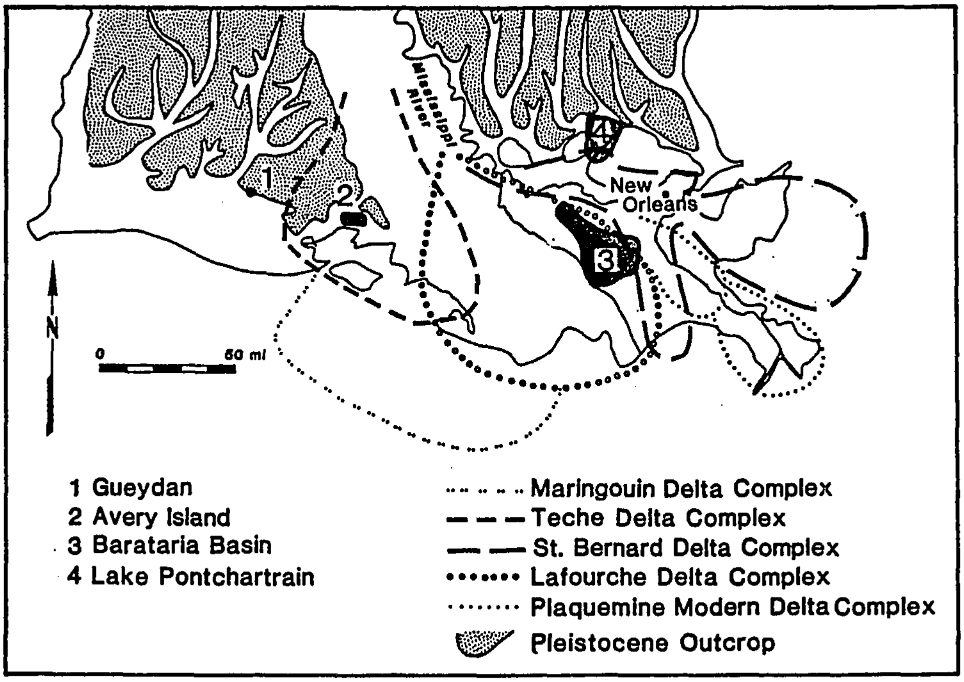

Figure 1 Location of study areas and Holocene Mississippi deltaic complexes (after Frazier, 1967).

BACKGROUND

Origin of peat

Peat is the accumulated remains of dead plants (Clymo, 1983) and - in this definition - can be of any botanical origin and any ash content[2]. Slightly more specific is the definition by ASTM (1969) (see p. 19 beds). Peat can be autochthonous (in-situ) or allochthonous (detrital). The latter is thought to be rarer in occurrence than the former (Galloway and Hobday, 1983), and was not a topic of investigation.

Autochthonous peat originates when dead plant matter accumulates below the water surface and undergoes physical and chemical changes (Clymo, 1983). It is as yet undetermined how much of the total mass of peat consists of either above- or below-ground biomass (shoot/root ratios, see Raymond, 1986). The physical and chemical changes are:

1) loss of organic matter,
2) loss of physical structure,
3) change of chemical state.

----

[2]This section is not intended as a treatise on terminology. Because peat is studied by botanists, geologists, and soil scientist, the problem of definition is vast and largely semantic. For literature on the subject, see Etherington (1983), Moore and Bellamy (1974), Soil Conservation Service (1971), Farnham and Finney (1965), Dawson (1956), Cowardin et al., (1979), Penfound (1952), Hofstetter, (1983).

Plant material consists of organic and inorganic constituents, the latter constituting 1-13% of the total tissue (Alexander, 1977). Organic constituents are cellulose and hemicellulose, lignin, water-soluble and ether-soluble components, and proteins. The bulk of plant matter is composed of cellulose, hemicellulose and lignin, with the latter being most dominant in wood (Alexander, 1977).

After death of the plant, microbiological processes cause decomposition of organic matter, with lignin decomposing at the slowest rate and large particles decomposing at a slower rate than small particles. In peat-forming environments like marshes and swamps[3], plant matter accumulates below the water table, where aerobic decomposition slows due to lack of oxygen and organic material may become preserved as peat.

Peat - as a sediment - can then be described according to a number of physical properties, the most important of which are: botanical composition, state of decomposition, bulk density, moisture content, organic matter content (ash content), and heat of combustion (Clymo, 1983). In addition, peat can be identified by its geologic setting (raised bog, back-barrier, deltaic, etc.). Invariably, the physical characteristics of peat will show a relationship

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[3]Penfound (1952) first distinguished "forested swamps" and "herbaceous marshes".

with the geologic origin, as suggested by Cecil et al. (1985). There are two environmental nutrient-related categories: eutrophic or oligotrophic. Eutrophic systems receive influx from nutrient-rich drainage waters (almost invariably laden with suspended sediment), whereas oligotrophic systems receive only nutrient-poor precipitation and consequently contain ombrotrophic bogs, usually with large amounts of mosses (Sphagnum spp).

Peats of the Mississippi Delta are eutrophic in origin. Even on abandoned delta lobes or in the central portions of large-scale interdistributary basins, runoff waters flow through peat accumulation areas, either after storms or after riverine floods. Thus, the inorganic component of peat may consist of authigenic silica (plant silica), biogenic silica (fresh-water sponge spicules), detrital silicates (clay), early diagenetic minerals (e.g. pyrite) and water-soluble salts (Brupbacher et al., 1973; Kosters and Bailey, 1983, 1986; Bailey and Kosters, 1983). Sphagnum is essentially absent (Hofstetter, 1983).

Deltaic peats and coals.

Most coal researchers, with exception of Cecil et al. (1985), were influenced by studies in the Mississippi Delta when interpreting the rock record. While previous studies in the modern Mississippi Delta provided an excellent basis for understanding the regional stratigraphy of organic-rich deposits, little was known about the quantity, quality, and internal variation of the deltaic peat beds with respect to their different depositional settings in the delta plain.

Recently, McCabe (1984) summarized depositional environments of coal-bearing strata. With respect to deltaic peats, he suggested that it is unavoidable to find high-ash peats in deltaic environments because of detrital influx, which may be absent in other sedimentary environments. If high quality peats are to accumulate in clastic sedimentary environments (like a delta), then, according to McCabe (1984), one should consider that peat accumulation is not exactly contemporaneous with clastic deposition: there has to be a time-lag between clastic sediment deposition and organic accumulation. This reasoning is more logical and less exclusive than that of Cecil et al (1985). McCabe (1984) also stated that deltaic coal-forming environments have been overemphasized in the literature, and suggest that present-day deltaic areas cannot provide good examples of modern coal-forming environments (see also Cecil et al., 1985), even though many coals have been interpreted as having a deltaic origin (Wanless et al., 1963; Cavaroc, 1969; Elliott, 1974b; Flores, 1979; Cleaves, 1980; Ryer, 1981; Tewalt et al., 1981; Galloway and Hobday, 1983). When comparing (deltaic) coals to peats of the Mississippi Delta, it should be kept in mind that global environmental differences exist between any of the coal ages and the Holocene. McCabe also stressed that other peat-forming environments should be more closely studied. While it is true that presently more than 65% of the world's peat resources is locked up in arctic tundra bogs (Clymo, 1983), it is unlikely that these bogs have a high preservation potential: changing environmental conditions in a continental setting cause peats to oxidize rather than to be buried by sediment - such as in a coastal or lacustrine setting - and become preserved.

While the Mississippi Delta may not contain sufficient quantities of high-quality peat for forming thick coals, insight into the factors controlling peat accumulation and into relationships between detrital clastic sedimentation and peat accumulation contributes to the understanding of deltaic coal-forming environments.

To the author's knowledge, the only other delta where peat deposits have been studied in detail is the Fraser River Delta in British Columbia (Styan and Bustin, 1983; 1984). The Fraser River Delta is very different from the Mississippi Delta; it covers an area of only 975 km^2 and has an average thickness of 110 m. The delta is rapidly prograding, situated in a temperate climate in a macrotidal area (5 m tide range). Sphagnum peat is common. Styan and Bustin (1983; 1984) augered the delta, giving little opportunity for reconstructing detailed stratigraphy; they concentrated on paleobotanical relationships and maceral types but did not do extensive stratigraphic correlations.

METHODS

Collection of cores and augers

Sampling in the field was performed by using a modified 5HP concrete vibrator and 7.5 cm-diameter thin-walled aluminum pipe. Locally, a MacAuley peat sampler was used, but the vibracorer was preferred: lithologic logging and log correlation is more precise using the whole cores produced by the vibracorer rather than the broken cores produced when using the MacAuley auger. Cores were taken to depths of 3 to 8 m, depending on local conditions. Vibracoring usually caused the core to be somewhat compacted, a process that occurred mostly in the topmost water-rich portion of cores. Assuming that deeper detrital sediments do not compact when cored, and knowing the exact depth of the bottom of the core barrel, compaction is calculated and the core length corrected. If compaction exceeded 20% of the total core length, the core log was not used for stratigraphic correlation.

Core depths averaged 405 cm in Barataria Basin, 246 cm in Gueydan, 323 cm in Avery Island, and 166 cm in Lake Pontchartrain. A total of 146 cores (about 500 m of section) provided a data base for the study.

Laboratory techniques

Moisture and ash determination

Each logged unit was sampled for determination of moisture and ash content. In this method, moisture content was determined by oven-drying the samples at 105°C for 24 hours. Moisture content is defines as:

[(wet weight - dry weight) / weight weight] x 100%

Organic matter content, or its complement ash content, was determined by burning the samples, after the moisture procedure was completed, in a muffle furnace at 555°C for 24 hours as well. Organic matter content is given as:

[(dry weight - ash weight) / dry weight] x 100%

Temperatures of 105°C were used according to the ASTM (1969) method. Moisture content is thus given as a percentage on an as-received basis, whereas organic matter (or ash) content is given as a percentage on dry-weight basis. Ash percentage is: [100 - organic matter %]

This high-temperature ashing technique has the disadvantage that minor amounts of artificial minerals can be created during ashing, something that is avoided when using low-temperature ashing (Bailey and Kosters, 1983).

Bulk density determination

Bulk density is defined as: [dry weight/wet volume] (g/cm^3). It was determined in the following manner: after splitting the core, a 5-cm long half-core sample was placed in graduated cylinder which was previously filled with 150 ml water. After the sediment was added, the volume of the displaced water was recorded as the volume of the sample. The total content of the cylinder (water + sediment) was then put in a beaker of known weight and placed in a drying oven at 105°C for 24 hours, after which the dry weight was established. Small, unmeasured, errors are inherent in these data because samples were not saturated with water prior to immersion, thus not taking air space into account.

X-Ray radiography

To prepare core sections for radiography, cores were split lengthwise in 25 cm-long sections. Each section was laid out on an especially made core slabber and sliced down to a thickness of 0.6 cm, using a potter's wire. Slabs were then covered in plastic wrap and labeled. Radiography consists of transmitting x-rays through the sediment onto x-ray film. Density, composition and particle orientation, among other variables, cause differential absorption and transmission of the x-rays through the material and onto the film. Film to source distance and exposure time can be varied depending on sediment type. A Norelco 150 kV Constant Potential Beryllium window X-Ray Tube, set at 48kV and 20mA was used.

Sediment identification and terminology

The description of organic sediments as used in this study has been influenced by that of Kearns and Davison (1983): the range of organic sediments was identified according to organic matter content: sediments with 0-5% organic matter (by dry weight) were described based on inorganic texture. Materials with 5-35% and 35-75% organic matter were classed "organic-poor" and "organic-rich", respectively. Peat was defined according to ASTM (1969): organic material of plant origin, excluding coal, with an organic matter content of at least 75% on a dry weight basis after loss on ignition at 555°C.

Different types of organic material were thus defined based on their organic matter content. Observations about botanical origin were only added in terms of the material being of marsh or swamp origin. Degree of decomposition was usually noted in terms of Von Post's (1924) classification of "fibric" (>2/3 fibers), "hemic" (1/3-2/3 fibers) or "sapric" (<1/3 fibers). It appeared that many peats were fibric and often of a swamp or flotant origin. In addition, many organic-rich horizons appeared to be hemic and often of a marsh origin. Saline marshes produced only organic-poor material in the subsurface.

GEOLOGIC SETTING

Regional setting of the Mississippi Delta

The Mississippi Delta plain has an aerial size of about 28,000 km^2 and drains a basin of 3.345 x 10^3 km^2 (Coleman, 1981). It is located at a latitude of 31° N, the climate being classified as humid (Critchfield, 1971). The river debouches in a tectonically unstable basin, the Gulf of Mexico. As a result of both this tectonic setting and the size of the drainage basin, a clastic wedge which is about 225 m thick at the mouth of the modern Balize Delta has been deposited during the Late Quaternary (Coleman and Gagliano, 1964; Gould, 1971). The Present Balize Delta can be classified as a fluvially dominated system (Galloway, 1975), or a Type I delta according to Coleman and Wright (1973). The northern Gulf of Mexico has a diurnal microtidal character (30 cm tide range). As a result, the influence of the tide dissipates quickly away from the coast and has generally disappeared about 50 km inland (Baumann, 1980).

Depositional environments of Mississippi Delta

Autochthonous Organic-rich sediments and peat accumulate in three different types of environments in the Mississippi Delta.

1. channel-fill deposits
2. blanket peat[4] deposits on abandoned delta lobes (as defined by Coleman and Smith, 1964)
3. interdistributary peats in interdistributary basins (as defined by Coleman and Smith, 1964).

Frazier (1967), Frazier and Osanik (1969), Frazier et al. (1978), Coleman and Smith (1964), and Coleman (1966) described the depositional setting of peat in the Mississippi Delta: blanket peats accumulate in coastal marshes on top of abandoned delta lobes and interdistributary peats develop in (large-scale) interdistributary basins during the final aggradational phase of deltaic sedimentation. Blanket peats can have a regional extent of several hundred square kilometers, whereas interdistributary peats are of more limited extent, because they are confined by alluvial ridges that form the basin margins. Fisk (1960) and Frazier and Osanik (1969) discussed the stratigraphy of deltaic peat deposits and concluded that peat accumulation preferably takes place at sites where vegetation (furthest from the natural levee) is unaffected by floodborne sediments. Close to the natural levee, overbank flooding will cause "splits" in the peat

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[4]These "blanket peats" are totally different from the ombrotrophic "blanket bogs" as defined by Moore and Bellamy (1974). The term "blanket peats" is kept here for consistency in deltaic literature.

deposits. Both Fisk (1960) and Frazier and Osanik (1969) did some analyses of ash content and mineral matter on samples of widely scattered areas. These analyses showed that most of their "peats" contained as much as 67% ash. However, material of this quality doesn't classify as peat when using ASTM's (1969) definition. These early studies on modern peats created many unanswered questions. And, with respect to the validity of deltaic environments as models of coal-formation: the sparse analyses did not indicate the abundant presence of high quality peats. In addition, thicknesses of organic-rich beds in the delta were thought insufficient to yield commercial-quality coal seams after peat-to-coal compaction.

Baumann (1980) and Delaune et al. (1978; 1983; 1984) showed that vegetation of eutrophic Gulf Coast marshes needs some detrital influx in order to continue vertical accretion. Unlike sphagnum peat bogs, Gulf Coast vegetation is unable to create a perched water table. Thus, in order to continue having a growth platform, some detrital influx is necessary to prevent the vegetation from "drowning" in a generally subsiding area.

Floating marshes

Floating marshes, also called "floating mats" (Cowardin et al., 1979) or "flotants" (Russell, 1939), are poorly understood, but possibly important to peat formation in the

Mississippi Delta (Frazier and Osanik, 1969). Russell (1939) described the vegetational and geographical characteristics of a flotant. In the initial stages of flotant development, an open body of fresh water is covered by floating vegetation such as waterhyacinth (Eichornia crassipes) and alligator weed (Alternanthera philoxerides). Through time a biological succession takes place, resulting in a more firm and solid marsh. Russell was of the opinion that the process is more important in the 20th century than earlier, because waterhyacinth and alligator weed were introduced by 20th century man. However, "live" floating marshes at present contain very few of these plant species (Sasser et al, 1983), and consists predominantly of Panicum hemotomum. Beneath the mat of floating vegetation, organic detritus from the underside of the flotant will be deposited as organic-rich material on the floor of the water body. The appearance of this material may resemble "fine detrital gyttja", a sediment formed of organic fragments usually too small to be identified (Morner, 1978). A similar organic sludge may be present underneath the rooted, floating mat (Sasser, 1986, pers. commun.). If the process is allowed to continue for sufficient time, the horizon of detrital organic matter will have become so thick that it meets the buoyant layer above. It is thought that typical downhole variation in organic matter content (true peat present in the center of the sedimentary column, as illustrated in Fig. 2) may sometimes reflect this accumulation process. On a generally subsiding area, flotants may therefore form relatively stable environments (Weinstein and Gagliano, 1984). Russell (1939) also postulated that flotants might originate by detachment of plants from the underlying soil in areas of subsidence. This hypothesis was probably incorrect since plant communities in non-floating environments do not have the capacity to become aquatic.

Deltaic coal literature rarely mentions floating marshes, although various schemes have been proposed for the origin of cannel coals (McCabe, 1984; Fielding, 1984a,b; Hook, in press). Presently, the literature emphasizes raised oligotrophic bogs (McCabe, 1984; Cecil et al., 1985; Esterle and Fern, 1986) as good examples of coal-forming environments. Phillips and Peppers (1984) argued that floating vegetation did not exist in the Carboniferous, but this theory is based on coal ball studies which may be very selective (Raymond, Scott, pers. commun.). Raised bogs may be only locally of value in explaining coal beds (Galloway and Hobday, 1983), since such a bog eventually experiences a nutrient deficit which will result in a limited thickness. In addition, most raised bogs are unlikely to become blanketed by clastic sediments in order to become preserved. Considering the importance of flotants may prove to be valuable in peat and coal research.

GUEYDAN AREA

The study area near Gueydan, in southwestern Louisiana (Fig. 2) is a filled channel of Pleistocene age, cutting the Pleistocene Prairie Terrace. The system is possibly related to a Late Pleistocene Mississippi River system (Howe et al, 1935; Van Lopik, 1955). Filling of the channel occurred during Holocene sea level rise. The vegetation is classified as fresh marsh (Chabreck and Linscombe, 1978). Coleman (1981) described the typical lithologic sequence of an abandoned meander or distributary: "lenticular bodies of fine-grained material interfingering with peats and transported organic debris. The final stage of filling is normally characterized by sediments with a high organic content, sometimes peat". Eleven cores were taken in Latanier Bayou (Fig. 3). Stratigraphic interpretation of a typical section is shown in Fig. 2. The bottom portion of the channel, just above the Pleistocene horizon, is filled with clays, on top of which organic-rich sediments have accumulated. A radiograph of the organic-rich sediments in core G 13 (Fig. 4) displays bedded structures thought to be characteristic of a channel-fill. Peat is generally present between about 1 and 2 m depth, except in the shallow northern portion of the channel where it occurs at the surface. This sequence is thought to reflect accumulation beneath a floating marsh or a typical marsh drowning sa-propelic zone.

An active flotant exists in the southwestern portion of Latanier Bayou, the mat of floating vegetation being only about 30 cm thick and floating on about 5 m of water. In the far eastern portion of Latanier Bayou, peat has not developed; only organic-poor and minor amounts of organic-rich material occur.

Results from paleobotanical analyses of a paraffin-mounted thin section of a sample from core G1 (Cohen, 1983) show that the vegetation of the peat-forming environments was of fresh water origin. Numerous Quercus (oak) and Pinus (pine) pollen were identified, adding to the interpretation that the marsh was relatively dry. This interpretation may partly be related to the sample's proximity to the northern shallow portion of the channel.

Figure 2 Gueydan: channel-fill deposit in Latanier Bayou. Upper part of figure shows stratigraphic cross section, where histograms along cores illustrate percent organic matter in the samples. Lower part of figure shows isopleth map of Latanier Bayou after Engineering Bureau Shutt and Sons (in Kress, 1980), and location of cross section.

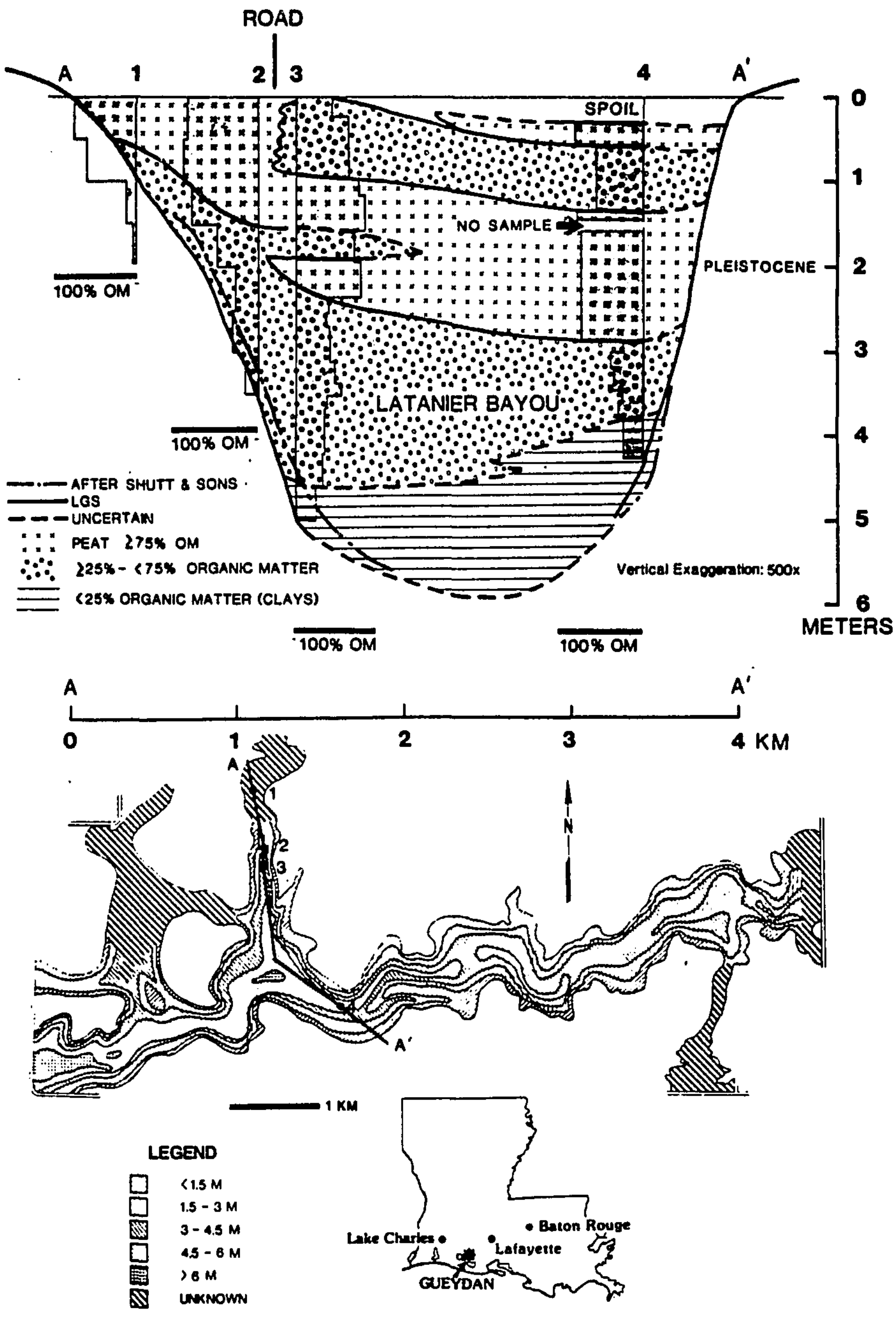

ROAD
A
1
2
3
4
A'
SPOIL
NO SAMPLE
PLEISTOCENE
LATANIER BAYOU
100% OM
100% OM
100% OM
100% OM
AFTER SHUTT & SONS
LGS
UNCERTAIN
PEAT ≥75% OM
≥25% - <75% ORGANIC MATTER
<25% ORGANIC MATTER (CLAYS)
Vertical Exaggeration: 500x
0
1
2
3
4
5
6
METERS
A
A'
0
1
2
3
4 KM
N
1 KM
LEGEND
<1.5 M
1.5 - 3 M
3 - 4.5 M
4.5 - 6 M
>6 M
UNKNOWN
Lake Charles
Lafayette
Baton Rouge
GUEYDAN

Figure 3 Gueydan: channel-fill deposit at Latanier Bayou. Central portion of Latanier Bayou (Fig. 2, location) with isopach of organic deposits containing more than 25% organic matter.

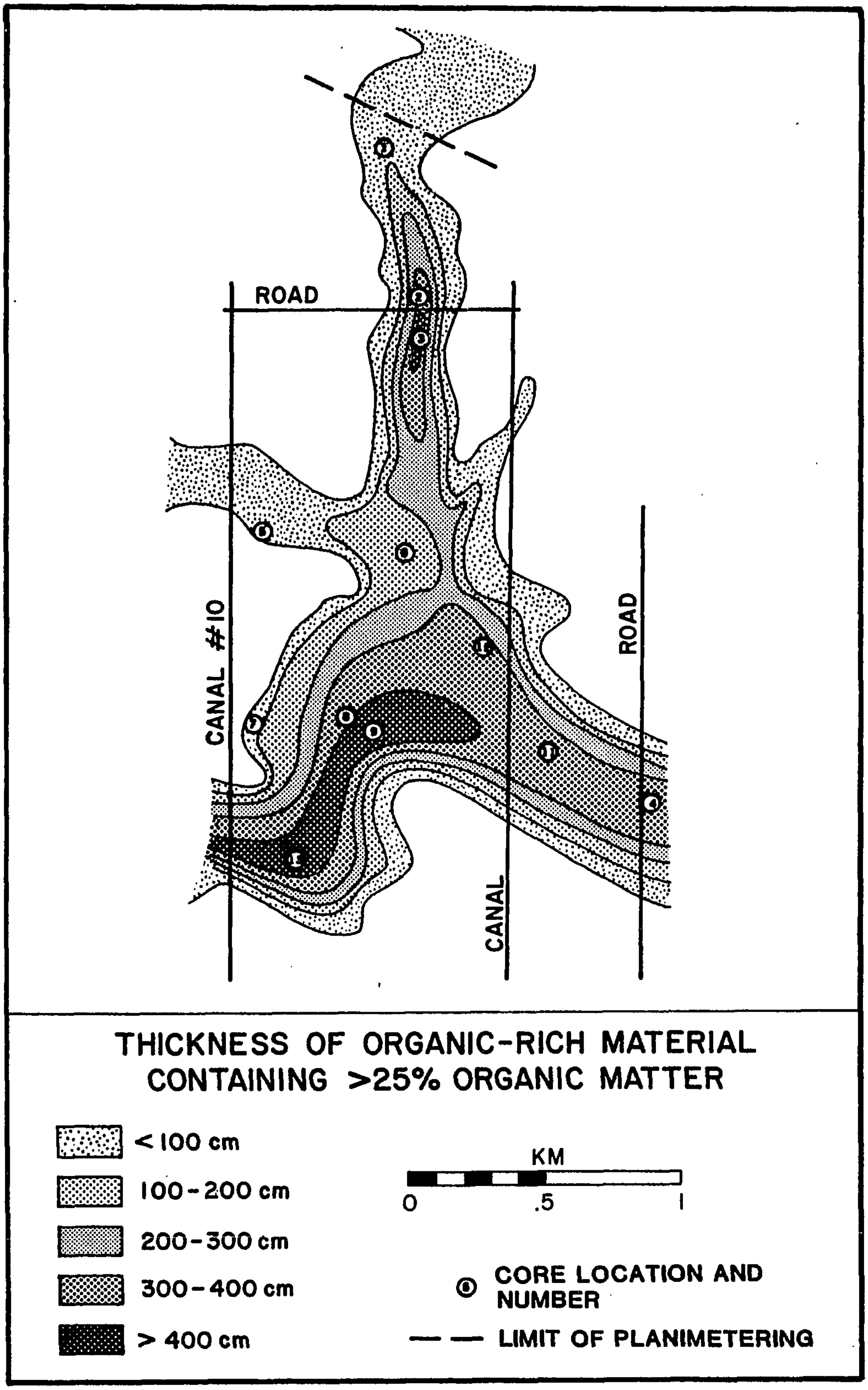
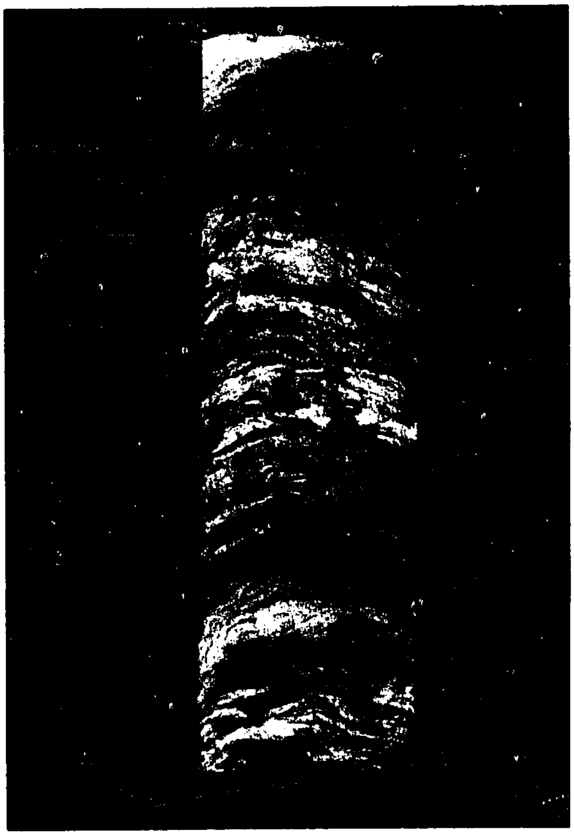

ROAD
CANAL #10
ROAD
CANAL
THICKNESS OF ORGANIC-RICH MATERIAL
CONTAINING >25% ORGANIC MATTER
< 100 cm
100-200 cm
200-300 cm
300-400 cm
> 400 cm
KM
0
.5
1
CORE LOCATION AND NUMBER
LIMIT OF PLANIMETERING

Figure 4 Gueydan: channel-fill deposit at Latanier Bayou. X-ray radiograph of organic-rich material at 350 - 375 cm depth in core G13 (Fig. 2, location). The lithology is identical to that in core G3, 300 - 400 cm depth. Radiograph shows characteristic finely bedded structure of lower portion of a channel-fill floating marsh.



AVERY ISLAND AREA

The Avery Island area is located in the westernmost portion of the Deltaic Plain (Fig. 1). This area consists of sediments of the upper delta plain of the oldest lobe of the Mississippi Delta, the Maringouin/Teche (Frazier, 1967; Kolb and Van Lopik, 1958). Holocene sediments in the study area are thin, the Pleistocene lying at only about 2-5 m depth. After the Maringouin-Teche systems were abandoned, the Mississippi Delta Complex shifted eastward and consequently, the area has not received a major clastic detrital influx in about 3000 years. The present surface is covered with a brackish marsh (O'Neill, 1949; Chabreck and Linscombe, 1978), consisting predominantly of Spartina patens.

Nine cores were taken in the area (Fig. 5). In each core a cypress swamp deposit (consisting of organic-rich material and abundant wood) is located on top of a massive appearing clay. The cypress swamp deposit is continuous in both dip and strike directions. The bottom of the peat horizon in core AI 3 yielded an average date of 4250 yrs BP. The cypress swamp deposit dips gently down towards the coast and contains two true peat beds. The top of the section displays a landward-thinning wedge of organic-poor deposits, representing recent saline marsh conditions. Coastal erosion after delta lobe abandonment caused introduction of salt water giving rise to surficial brackish and saline marshes, preserving less subsurface organic matter than fresh swamp vegetation. The fact that high-quality peat does not originate in saline marshes has been recognized in the literature and attributed to three factors:

1) increased detrital clastic influx, predominantly by storms (Galloway and Hobday, 1983)
2) increased export of organic matter by tidal flushing
3) increased pH and effectiveness of microbiological organisms in breaking down organic matter (Renton et al., 1979; Patrick, 1985, pers. commun.)

Renton et al. (1979) stated that a transgression not only terminates peat accumulation but, in addition, that higher pH will increase decomposition of transgressed peats. No evidence for this process has been found in the Avery Island area.

Results of botanical analyses of paraffin-mounted thin-sections from the central portion of the peat horizon in core # AI-9 (Cohen, 1983) confirm the fresh Taxodium (cypress) swamp origin. The thin-sections also displayed common occurrences of pyrite and fresh water sponge spicules. An x-ray radiograph from these peats (Fig. 6) shows well-rooted peat with abundant diagenetic alterations.

Although only a small area was cored, other studies have shown that extensive peat horizons are present in the area between Bayous Sale and Cypremort (Coleman, 1966; Kearns et al., 1982). Peats in that area, described as blanket peats (Coleman, 1966; Coleman and Smith, 1964), correlate stratigraphically with those in the Avery Island area. With minimal subsidence of less than 0.1 cm/yr (Coleman and Smith, 1964) and absence of any detrital influx, this area will, as a whole, yield a large quantity of high-quality peats.

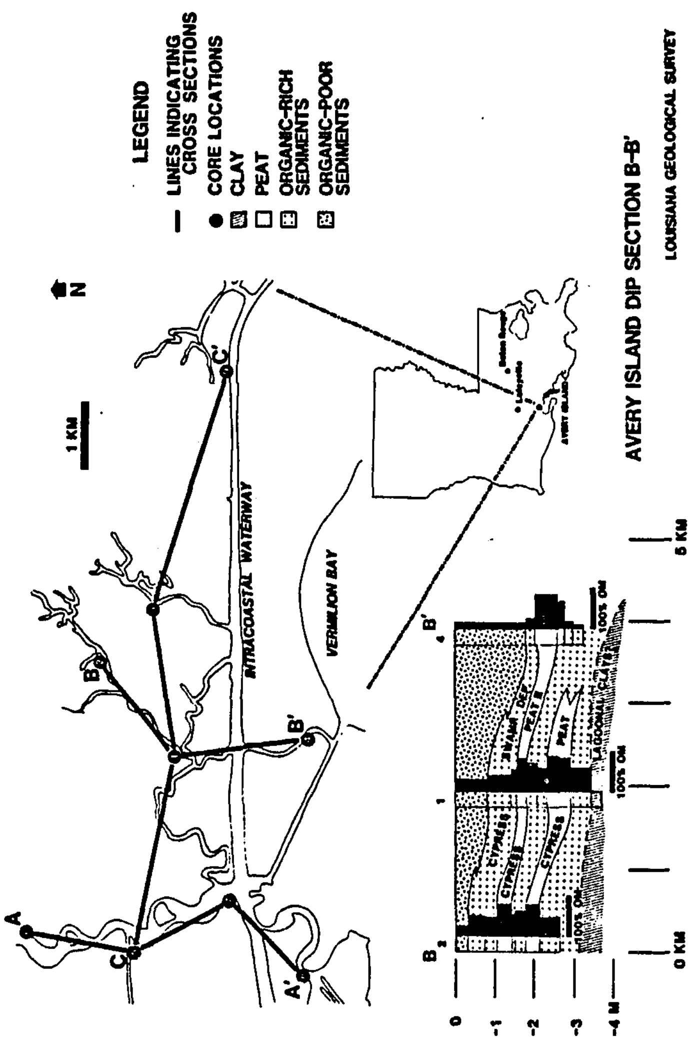


Figure 5 Avery Island blanket peat deposit. Figure shows location of 9 cores and 3 stratigraphic sections. Dip-section B-B' is also shown. The dip-section displays two peat beds of swamp origin, incorporated in organic-rich woody swamp material, overlain by a landward thinning wedge of post delta lobe abandonment organic-poor saline marsh deposits.

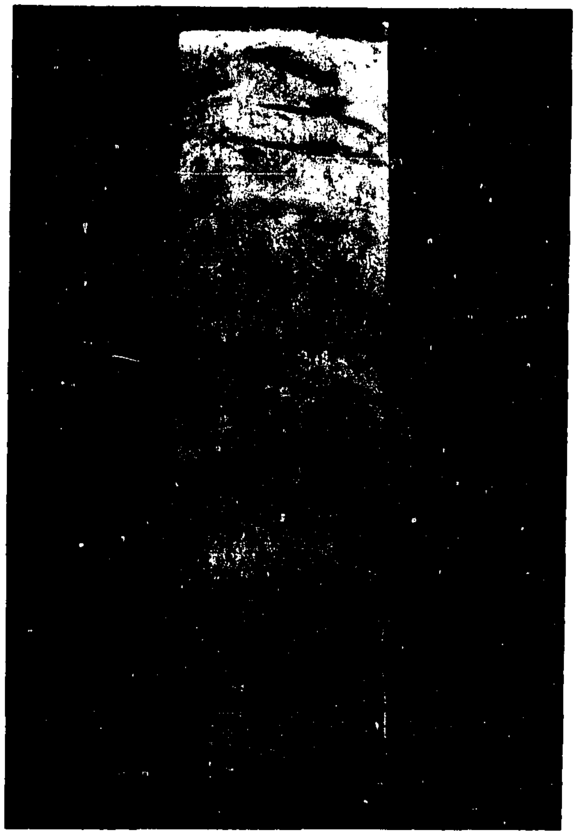


Figure 6 X-ray radiograph of peat (lithologic unit), in AI 1, 125 - 150 cm depth. Original was 25 cm long, 7 cm wide. In these fresh water swamp peats, presently inundated by salt water, most roots have remained diagenetically unaltered, but many clusters of white, diagenetic features can be observed. Most of these features prove to be pyrite.

LAKE PONTCHARTRAIN AREA

The Lake Pontchartrain area (Figs. 7, 8) represents a delta flank basin between the old course of the Mississippi River and the Pleistocene uplands. Until very recently, the area was dominated entirely by fresh water. <u>Taxodium</u> (cypress) and <u>Nyssa</u> (tupelo gum) together make up beautiful and extensive hardwood swamps in this region. The Pleistocene Prairie Terrace crops out at the northern boundary of the area and lies at about 10 m depth underneath the Mississippi River (Frazier, 1967). Frazier (1967), determined that <u>Taxodium</u> swamps have existed for the last 3000 years in this region.

Most of the samples in this area came from auger holes that penetrated not further than 1-1.5 m. The presence of a continuous floor of hardwood logs at that depth made it impossible to core deeper. Most augers contained beds of peat and as much as 25% of all sections consisted of peat. Botanical analyses of paraffin-mounted thin-sections (Cohen, 1983) classified these peats as hemic, persistently wet, and of a fresh-water <u>Taxodium</u> swamp origin. Fresh water sponge spicules occurred commonly in the thin-sections. This area is probably the best example of a modern coal-forming environment in the Mississippi Delta. A thin Holocene package has prevented excessive submergence rates and the relatively fixed position of the Mississippi River has created a basin wedged between it and the Pleistocene uplands on the northern edge. Moreover, the area has not received clastic deltaic influx since the abandonment of the Cocodrie system about 4000 years BP. Such isolated, sheltered basins have been envisioned by some researchers in ancient systems (Calder, in press). Howe et al. (1935) located a small area with peat in a sheltered spot between the Atchafalaya River and the Teche levee, north of Franklin. This area is presently built up, but represents a similar setting at a much smaller scale.

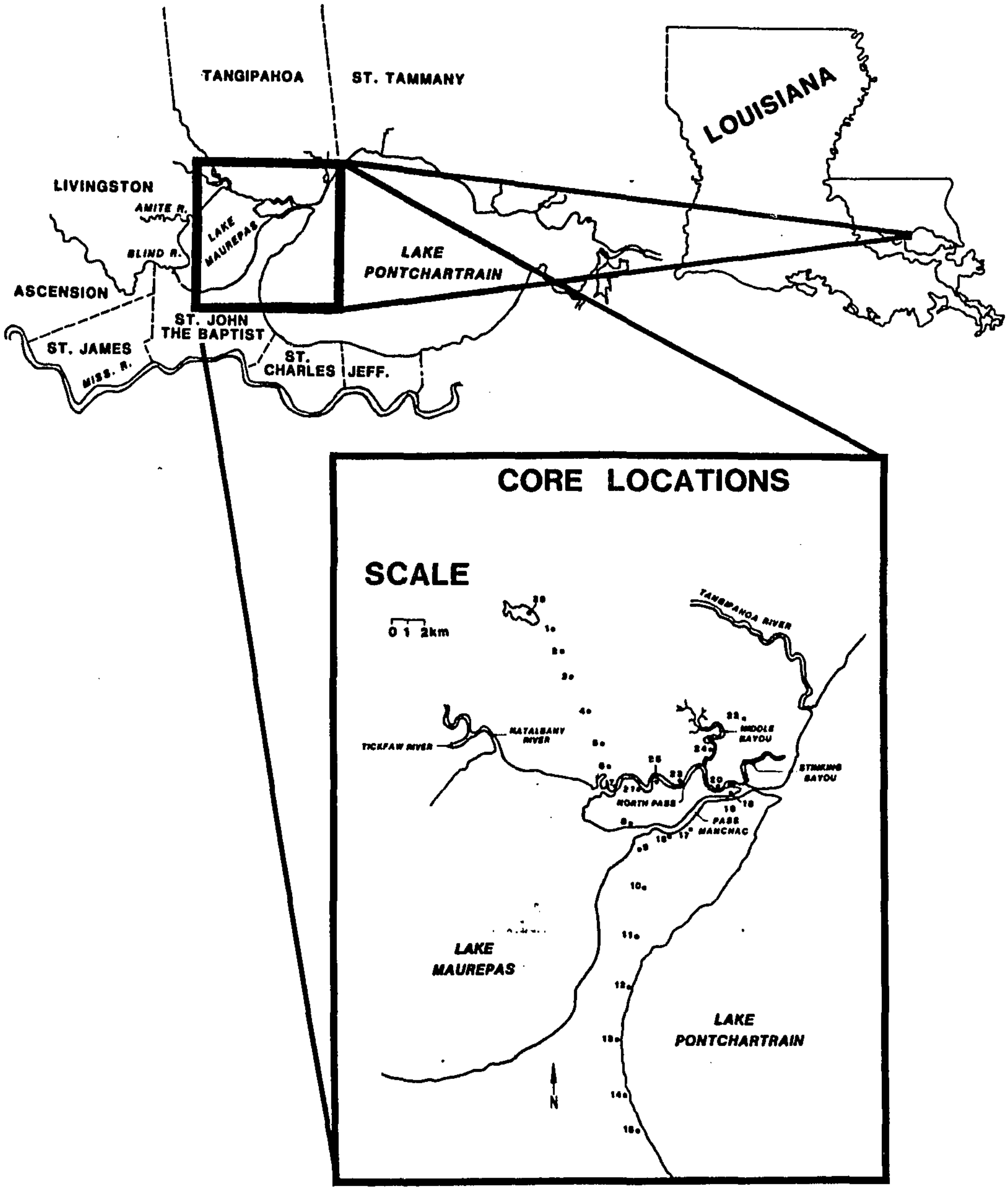


Figure 7 Lake Pontchartrain area: location of auger holes

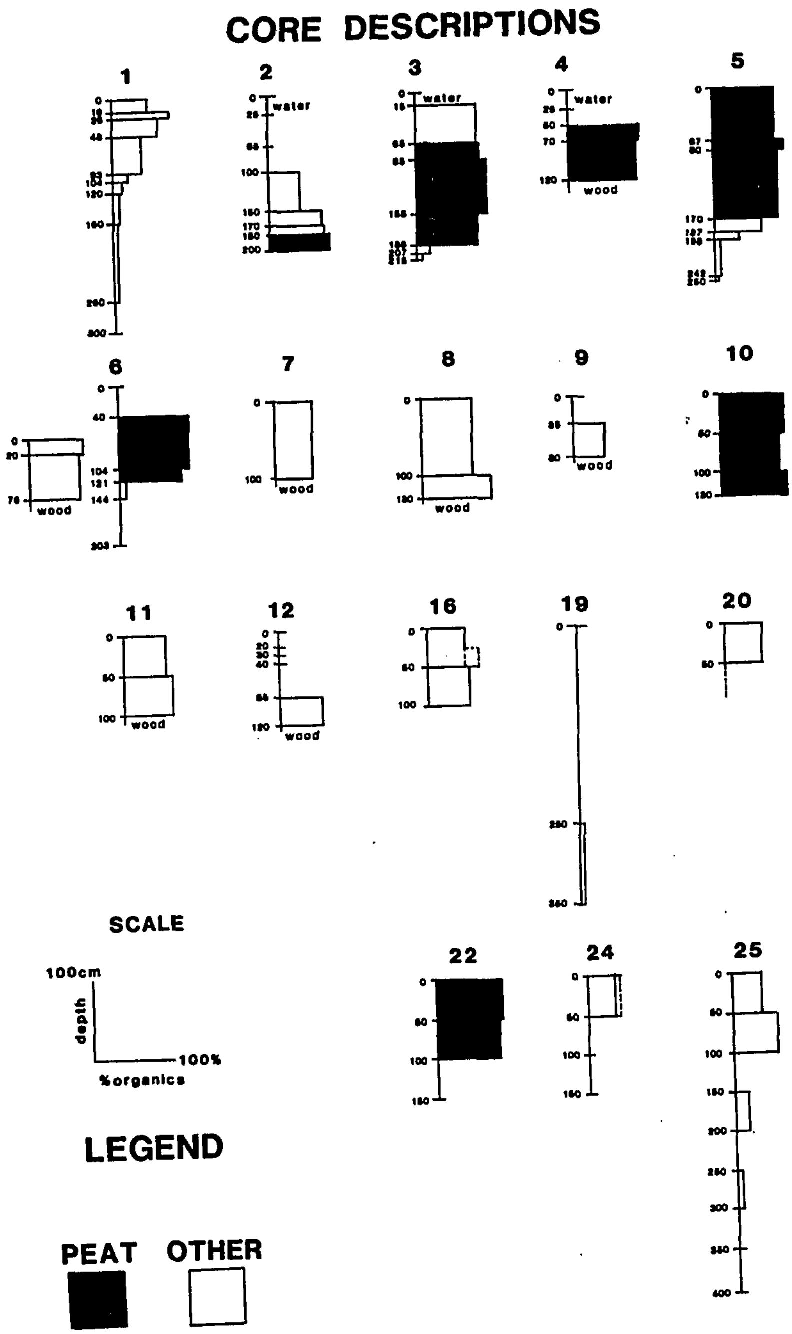


Figure 8 Lake Pontchartrain area: organic matter content of samples.

BARATARIA BASIN

The term large-scale interdistributary basin.

The distinction between large-scale interdistributary basins and small-scale interdistributary bays should be made. A large-scale interdistributary basin[5] (Fig. 9) is located between distributaries of different delta complexes within the same broad deltaic plain and has become isolated as a result of switching of major deltaic complexes. It represents the final aggradational stage within one cycle of deltaic sedimentation, and a relatively long time period is involved in the accumulation of organic sediments. A vertical line on Frazier's (1974) diagram (Fig. 9) indicates its position in time and place. Small-scale interdistributary bays are located between the distributaries of one single delta lobe, such as those of the Present Balize Delta, and contain more progradational sediments. During a short interval, a hiatus in clastic sedimentation occurs; this hiatus is used for accumulation of organic sediments, and is much shorter in duration than for large-scale interdistributary basins. Abandoned delta lobes and large-scale interdistributary basins are located away from hurricanes, and from daily influences of waves and tides, while an active prograding system is in close proximity to such processes.

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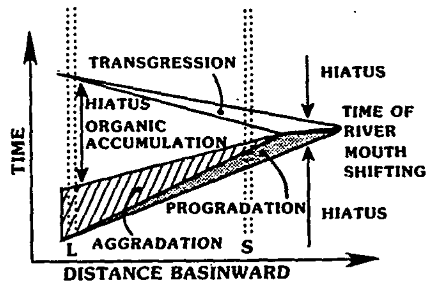
[5]termed "inter-levee basin" by Weinstein and Gagliano.

INTERDISTRIBUTARY BASINS		
VARIABLES	LARGE-SCALE	SMALL-SCALE
DISTRIBUTARIES	MORE THAN ONE DELTAIC SYSTEM	ONE DELTAIC SYSTEM
DISTANCE BETWEEN LEVEES	MAX. 50 km	MAX. 15 km
DAILY TIDAL INFLUENCE	SMALL	LARGE
DAILY WAVE INFLUENCE	SMALL	LARGE
RIVERINE INFLUENCE	SMALL	LARGE
LAKES	POSSIBLY LONG-LIVED AND LARGE	SMALL, IF AT ALL EXISTENT
SWAMPS AND MARSHES	THICK, EXTENSIVE	THIN, RESTRICTED



(FRAZIER, 1969)

S - SMALL-SCALE INTERDISTRIBUTARY BASIN

L - LARGE-SCALE INTERDISTRIBUTARY BASIN

Figure 9 Different features of small- and large-scale interdistributary basins, dominated by regressive and aggradational processes, respectively.

Physiography.

Barataria Basin (Fig. 10) has its apex at Donaldsonville, where Bayou Lafourche branches off the Mississippi River. Total length of the basin is about 150 km and it is about 50 km wide at the Gulf of Mexico. Existence of the basin is the result of the interplay of different Mississippi delta complexes (Adams et al., 1976; Coleman and Gagliano, 1964; Frazier, 1967; Weinstein and Gagliano, 1984). Fisk (1944) and Frazier (1967) state that the modern Mississippi River, in the upper portion of the basin, follows a course that has probably been occupied several times since the early Holocene because the Present river cuts deeply into the Pleistocene strata.

A large-scale interdistributary basin will be completely filled with different types of sediment during a regressive phase in deltaic sedimentation. Because such a basin is located between two different deltaic complexes, filling takes about twice as much time as the typical period needed to complete one cycle of deltaic sedimentation. Such a deltaic cycle lasts about 1500 years (Frazier, 1967). Consequently, filling of a large-scale interdistributary basin takes about 3000 years.

Presently, the diversion of deltaic sedimentation away from Barataria Basin (See Fisk, 1952) has caused a reversal to a transgressive stage: water bodies are increasing in size at the cost of swamps and marshes, and the brackish/saline boundary moved inland at a rate of about 3 km over 30 years (Chabreck, 1970).

A variety of physiographic features characterize a basin of this type. These features can be divided into ones that have their origin in clastic sedimentary processes and ones that originate from organic accumulation processes. The physiography consists of lakes, lacustrine deltas, natural levees, crevasse splays, drainage channels, and extensive swamps and marshes. Open water bodies generally increase in size Gulfward. The seaward portion of the basin consists mainly of the interdistributary bay. Lakes tend to be of different sizes, ranging from small ponds a few meters across (O'Neill, 1949; Russell, 1936) to large intrabasin lakes, such as Lac des Allemands and Lake Salvador. Channels and crevasse splays have debouched into the basin, sometimes disrupting peat accumulation and often creating small lacustrine deltas. Vegetation ranges from continuous forested fresh water swamps in the updip portion of the basin, to treeless saline marshes near the coast (Chabreck and Linscombe, 1978).

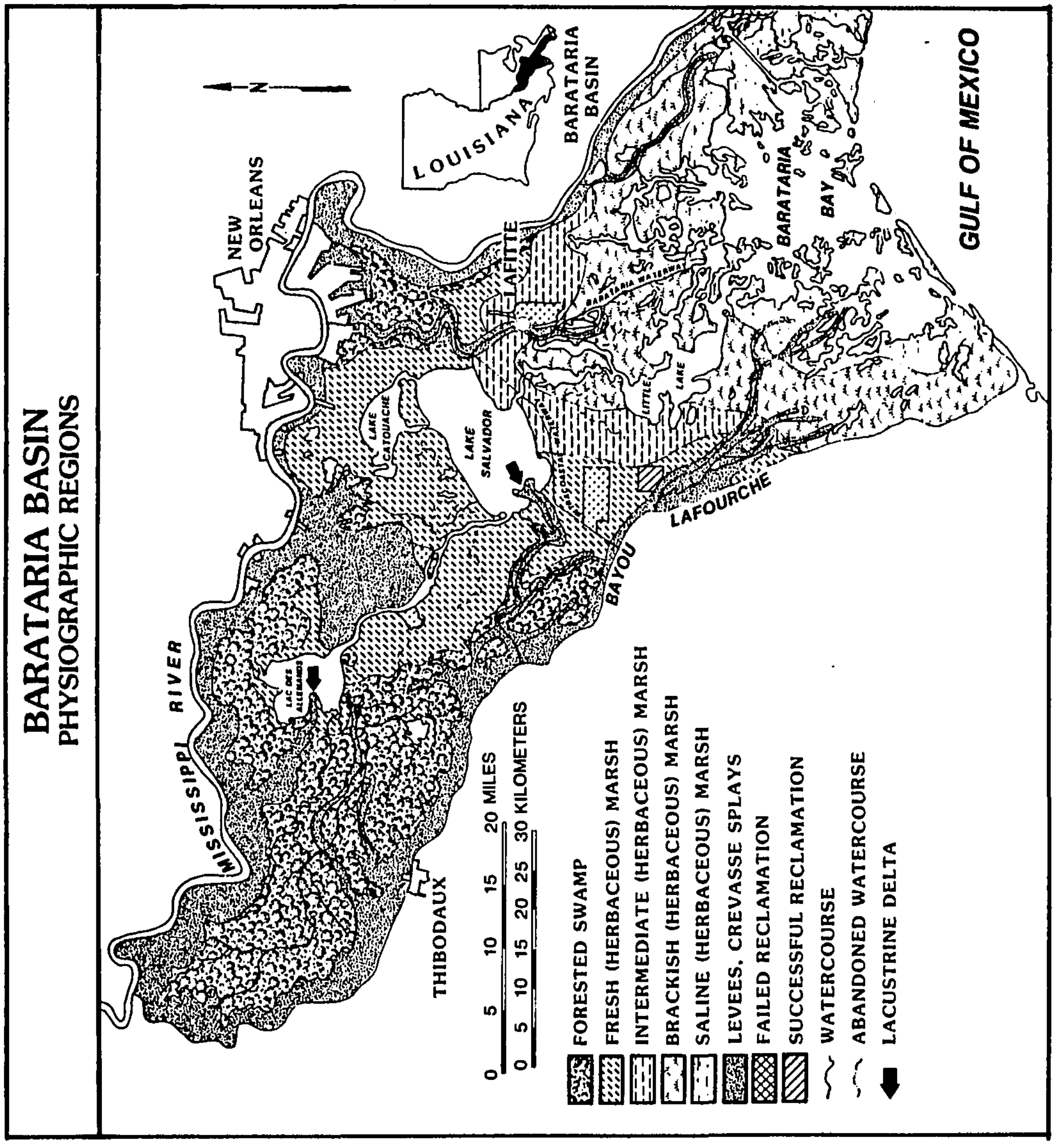


Figure 10 Physiography of Barataria Basin. Vegetation zones after Chabreck and Linscombe (1978).

Lithostratigraphic units

This section will systematically describe the lithostratigraphic units. The sequence in which they are discussed basically follows the series of geologic events that shaped the basin, as summarized in the two sections hereafter.

Inorganic clastic units

A - Open bay.

This unit is only encountered in some of the deeper cores in the upper basin (BB 87, see Appendix for core logs) and in a few of the southernmost cores in the lower basin (BB 25 and BB 48). The top of the unit occurs at 6 m depth along cross sections H-H' and J-J' (Figs. 14 and 15; Figs. 11 and 12, location; Fig 13, legend) and at 3.5 m depth along G-G' (Fig. 16). The unit is characterized by thoroughly bioturbated fine sands containing numerous *Rangea cuneata* specimens. The mollusk *Rangea cuneata* occurs in microsaline (about 5000 TDS) environments (Hopkins 1973). Many of the specimens were intact, a few even hinged. Intact and broken shells occur in distinct, separate zones (BB 87), indicating that the environment was periodically disturbed by storms. Hinged *Rangea cuneata* ^{14}C dates range from 4000 - 2300 yBP.

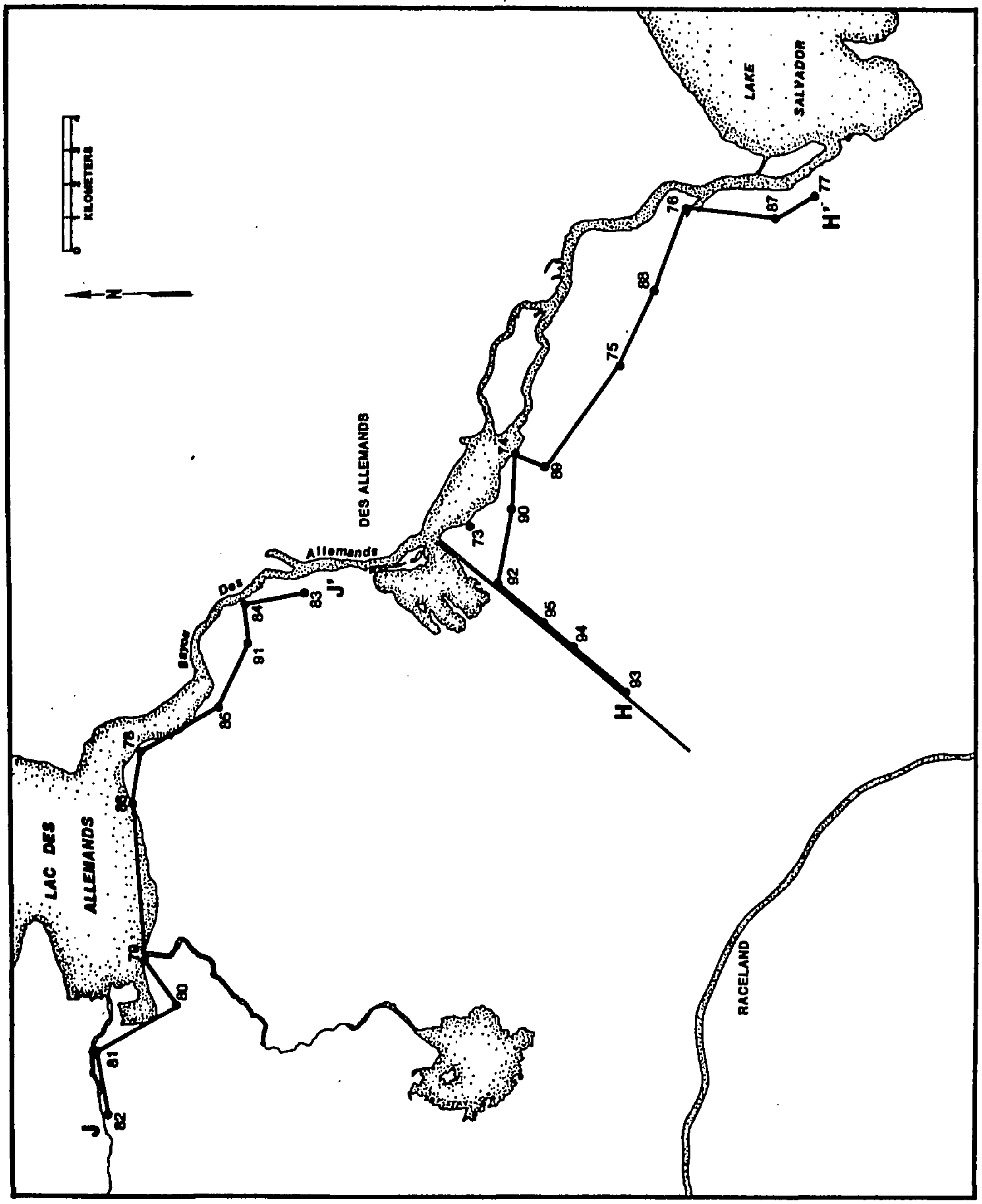


Figure 11 Location of cores and cross sections in upper Barataria Basin.

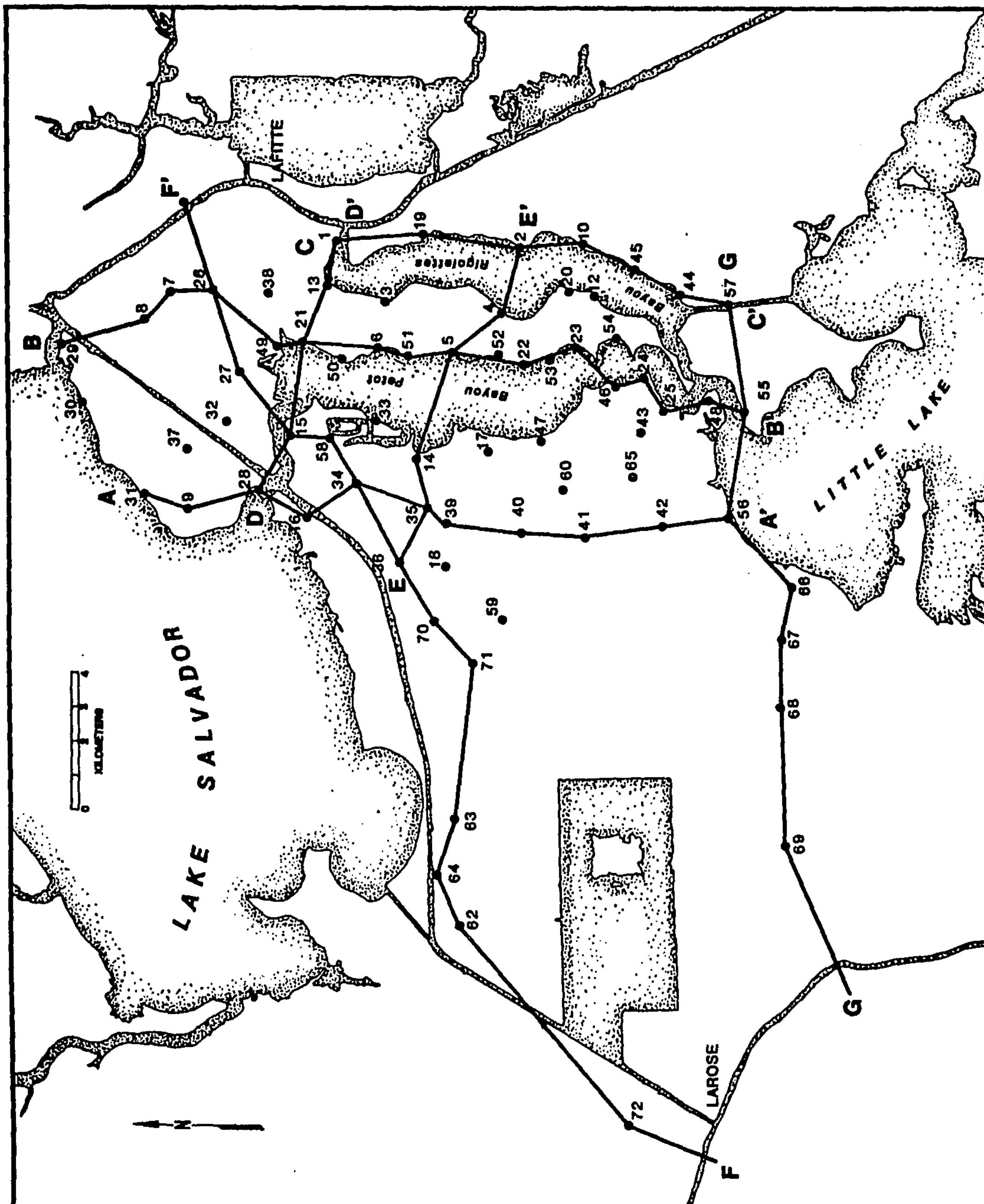


Figure 12 Location of cores and cross sections in lower Barataria Basin.

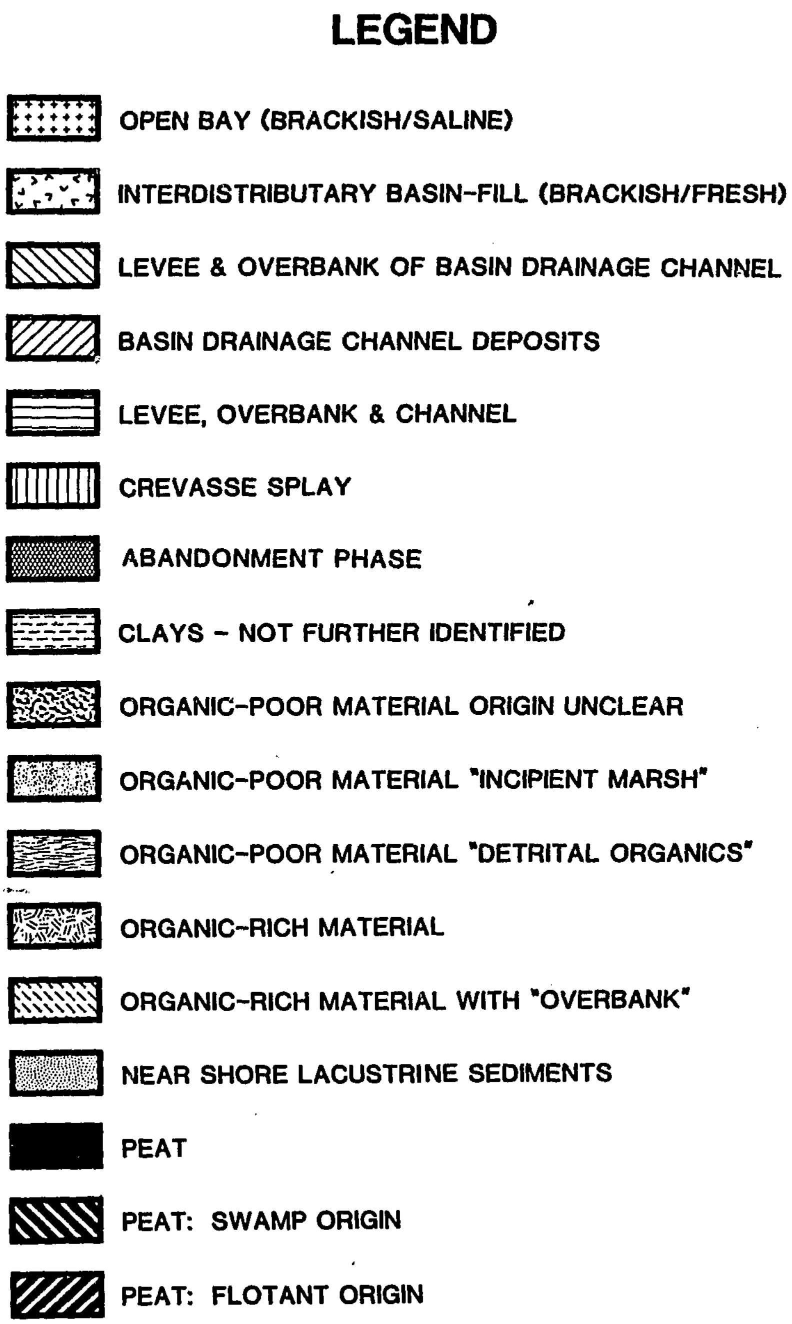
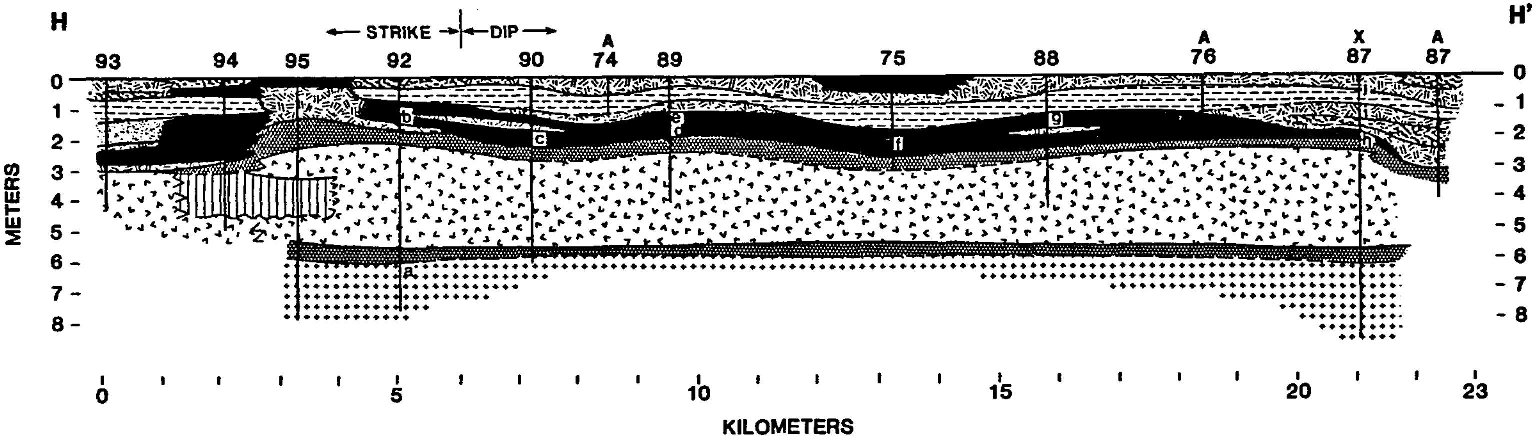


Figure 13 Legend for stratigraphic cross sections (Figs. 14, 15, 16, 19, 20, 27, and 28).

Figure 14 Barataria Basin - Stratigraphic cross section H-H' (for location and legend see Figs. 11 and 13). Note that peat beds are continuous and that almost all peats are located directly on top of the abandonment phase.



C[14] DATES Yrs. B. P.

a: 4240± 85 (shell)
b: 1860± 75
c: 2305± 80
d: 2530± 80
e: 920± 150
f: 2015± 170
g: 1280± 75
h: 2135± 80
i: 1005± 150
j: 540± 145

X: core (partially) radiographed

Vertical exaggeration: 500X

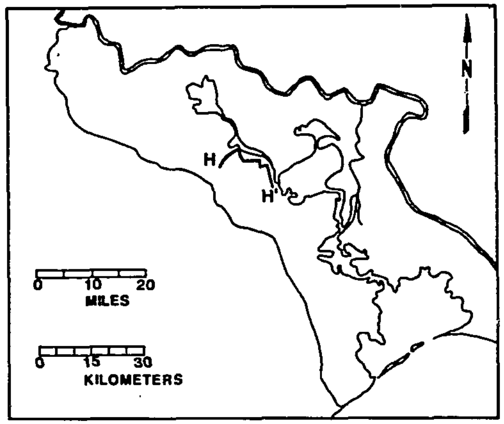
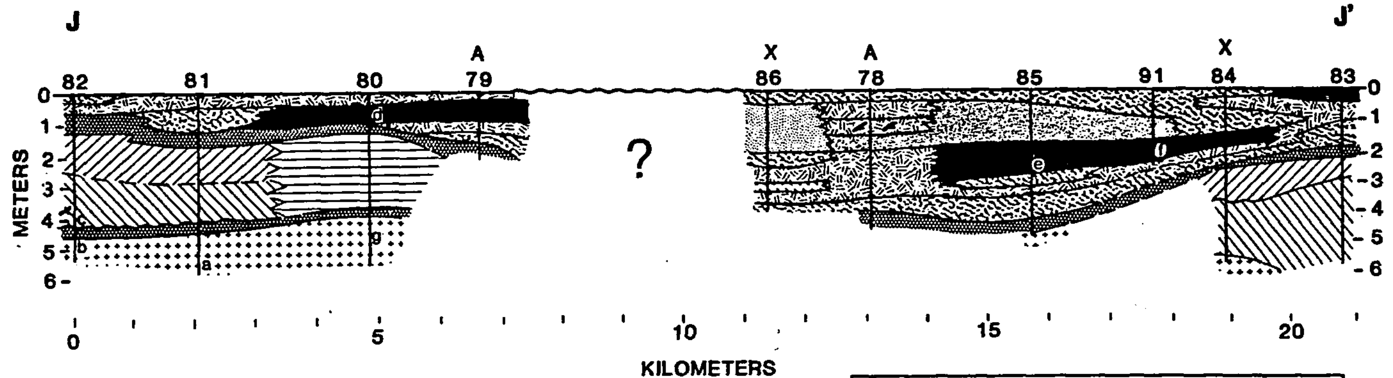


Figure 15 Barataria Basin - Stratigraphic cross section J-J' (location and legend, Figs. 11 and 13). Shallowness of the depression is partially the result of coring close to basin drainage channel in BB 82, 81, 80, 84, and 83. Situation under Lac des Allemands uncertain (question mark).



C^{14} DATES Yrs. B. P.

a: 2425 ± 130 B.P. (shells)
b: 2380 ± 75 B.P. (shells)
c: 650 ± 115 B.P. (wood)
d: 470 ± 115 B.P. (peat)
e: 2305 ± 80 B.P. (peat)
f: 1695 ± 130 B.P. (peat)
g: 2515 ± 130 B.P. (shells)
h: 2540 ± 80 B.P. (peat)
j: 1665 ± 80 B.P. (peat)

A: Auger : Wood
X: Core (partially) radiographed

Vertical exaggeration: 500X

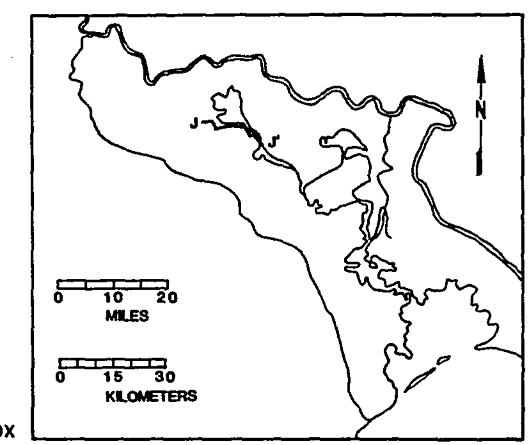
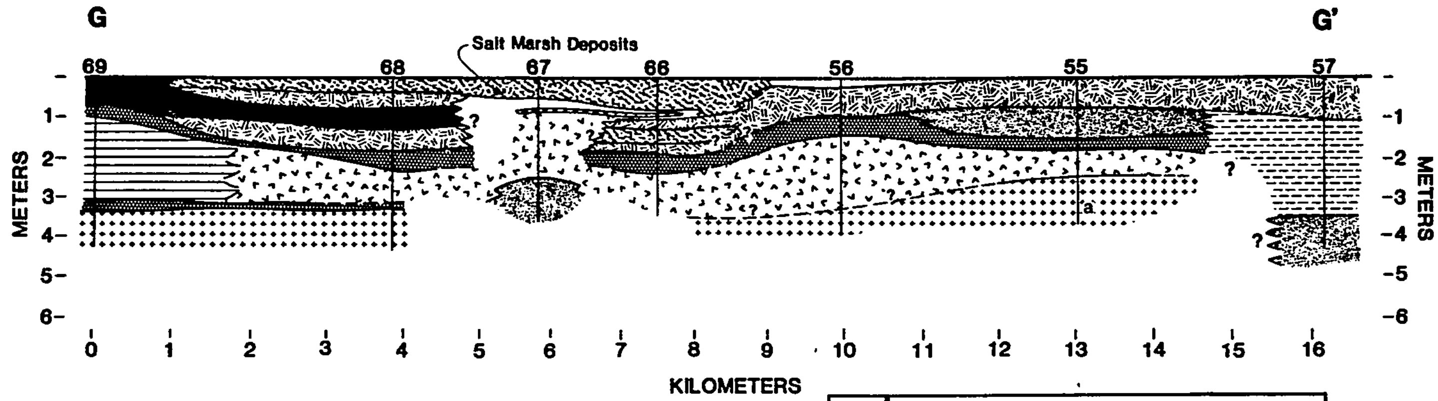
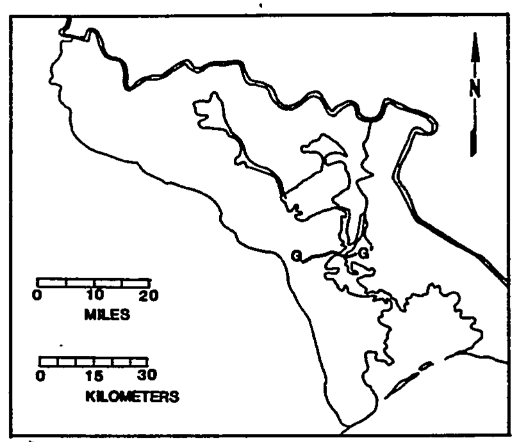


Figure 16 Barataria Basin - Stratigraphic strike section G-G' (for location and legend see Figs. 12 and 13). Encroachment of salt marsh shows as organic-poor top horizon in westernmost portion of section (cf. core 69 and 68). Peats are only present in the far western end of the section, close to the Lafourche distributary system.





C^{14} DATE Yrs. B.P.

a: 3050 ± 120 (shells)

Vertical exaggeration: 500X

B - Restricted basin.

Around 2500 yBP, the basin became a confined area and was filled with overbank sediments from either side (lobes 6 and 7[6]). The resulting unit is very distinct and was found mostly in the deeper cores in the upper basin. Thickness of this unit in the lower basin is undetermined because of much shallower coring. The unit consists of alternating beds of sandy silt and clay, usually in normally graded sets. Co-sets frequently display scoured bases. Parallel laminations dominate, but isolated ripples are occasionally found in the coarser lower portion of each co-set. Siderite horizons occur commonly in this unit. Figures 17 and 18 show X-ray radiographs of the unit in cores BB 87 and 71. In Fig. 17, lighter areas are coarser grained sediment, darker areas finer sediment. Sharp bottoms of darker areas indicate scour. A siderite band is visible in the lower portion of the radiograph. Curtis et al. (1975) discussed detailed chemical and isotopic (^{13}C) composition of siderite bands in shallow marine shales in the Westphalian of northern England. They concluded that:

> "the earliest siderite formation, containing mostly $FeCO_3$ and $MnCO_3$, probably took place very shortly after deposition in sediments that were slightly coarser-grained than the average shales. The Fe^{2+} and Mn^{2+} were made available as a result of initial reduction processes" (see also Patrick and DeLaune, 1977) "and

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[6] lobe numbers after Frazier (1967)

CO_3^{2-} due to anaerobic oxidation of organic matter (methane production). After burial, but still during very early diagenesis, siderite became more enriched in Ca^{2+} and Mg^{2+} and sequential CO_3^{2-} had a more marine source."

Each graded unit does not indicate a yearly (spring time) overbank event since the base of each co-set is often erosional. It is difficult to estimate the sedimentation rate of this unit, because of the apparent contrast in Rangea cuneata ages (cores 92 vs 82, 81, and 80). It is at present unclear whether the younger Rangea ages are from recrystallized shells. Fig. 18 illustrates the top of the basin-fill sediments. Rooting indicates occupation by plants after active overbank sedimentation ceased.

C - Other coarse-grained clastic units: Natural levee, crevasse splay, basin drainage channel, lacustrine deposits.

These are 4 different lithostratigraphic units, but they were only occasionally encountered and do not form a major part of the study. Therefore they are grouped together.

C-1 Natural levee

This unit was encountered in core BB 72 along C-C' (Fig. 19) and in BB 29 and BB 80. Along C-C', the unit is predominantly clay-sized, while in BB 72 a definite finingupward trend can be noticed and tabular cross-beds, detrital wood and rooting tend to be common. Oxidation was only common in BB 72 and 80. It is thought that much of the Bayou Barataria levee was nearly subaqueous at the time of deposition, a hypothesis also supported by Weinstein and Gagliano (1984).

C-2 Crevasse splay

This unit was only encountered in cores BB 94 and 95. The unit shows a scored base with associated rip-up clasts in BB 94, abundant organic fragments, some parallel lamination, tabular cross-beds and bioturbation.

C-3 Basin drainage channel

This unit was encountered in BB 81, 82, 83, 84, 58, 15, 51, and 28 and is characterized by a sharply scoured base, and low-angle cross-stratification. There are some isolated ripples and minor amounts of convolute bedding. The unit is commonly burrowed and rooted. The scour at the bottom was probably significant. In BB 82 (J-J', Fig. 15), <u>Rangea cuneata</u> in the top of the open bay unit dates about 2400 yrs BP and a piece of wood above the scoured base of the channel fill dates 650 yrs BP. Along A-A' (Fig. 20), the basin channel contains an organic-rich unit next to it. It is thought that this lowermost organic-rich unit (Phase A) originated next to and on top of the levees of the early basin drainage channel.

C-4 Near shore basin fill and near shore lacustrine.

These two units were encountered in only 3 cores (BB 93, 94, and 86) (H-H' and J-J' Figs. 14 and 15). They are very similar and thus grouped together even though the unit in BB 93 is distinctly coarser grained than in BB 86. The near shore basin fill, with mudcracks, wavy lamination, siderite horizons, rooting and organic fragments is slightly coarser-grained than the near shore lacustrine unit with more parallel lamination. Both contain organic fragments incorporated in the near shore sediments from nearby swamp and marshlands. Similar sediments were recognized by Fielding (1984a), in the Carboniferous of Northumberland.

D - Abandonment phase.

The sediments representing the abandonment phase are puzzling in nature. They can be found on top of lithofacies A and B. The unit consists of clay and is never more than about 50 cm thick, yet laterally very persistent (H-H' and J-J', Figs. 14 and 15). Along cross sections in the lower basin, the unit could not be distinguished because cores were too shallow. The unit is commonly rooted, contains significant amounts of fine organic debris and an occasional wood fragment. It might represent an "underclay" in coal terminology. Leaching with low pH water (4 to 5, Brupbacher et al. 1973) during early diagenesis causes underclays to have specific mineralogic characteristics (Cohen, 1973; Galloway and Hobday, 1983). It is curious that this clay-rich unit is so laterally continuous. Lithologically, the unit is very distinct (BB 89, 90, 92, and 94): examination by X-ray radiography shows that the unit is commonly massive in appearance, with the exception of plant material (Fig. 21). The literature contains little on the origin of massive muds: classic theory (Blatt, et al. 1973) dictates that massive sands are deposited either by very rapid deposition from suspension or from highly concentrated sediment dispersions. It seems that the clay-rich abandonment phase could represent a quiescent phase during which conditions were changing, while clays settled out of suspension in relatively calm water. Since organic-rich material and peat frequently occur on top of the unit, these clays may represent the "time lag" needed between the deposition of detrital sediments and peat accumulation (McCabe, 1984). Kaiser and Ayers (1986, pers. commun.) have suggested that underclays form a necessary hydrologic factor in a peat-forming system: the presence of a clay unit on top of a sandy unit may force water from the aquifer to the surface, thus creating permanently wet conditions.

Figure 17 X-ray radiograph of basin-fill (lithologic unit B) in BB 87, 350-375 cm depth. Original is 25 cm long, 7 cm wide. Inclination of beds along edges is due to coring disturbances. Lighter horizons are denser and contain sandy silt, darker ones are clayey and contain organic material. Note sharp bottoms of coarser beds and incorporated organics. Siderite horizon (indistinct white area) visible in lower portion of radiograph. Most bedding in this unit is parallel, and normally graded units shown here are common.

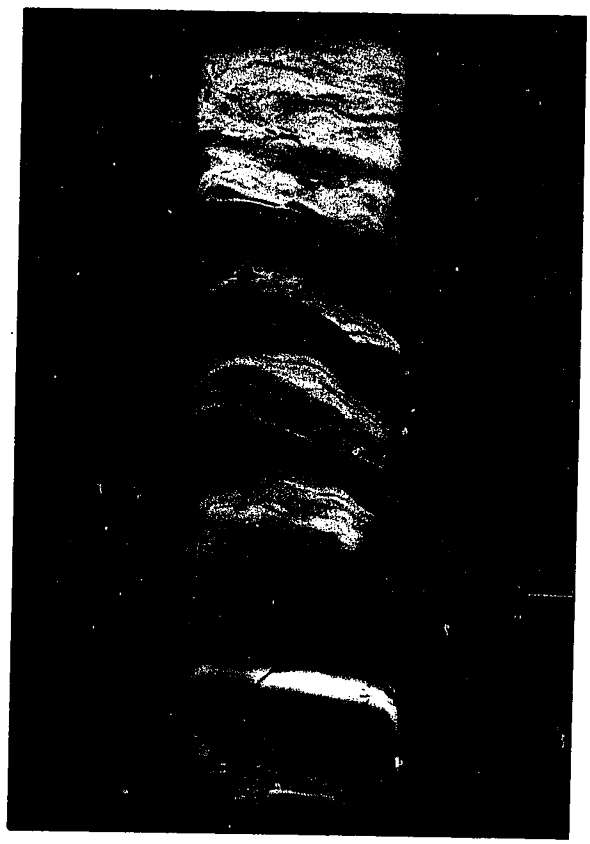


Figure 18 X-ray radiograph of top of basin-fill (lithologic unit B) in core BB 71, 200-225 cm depth. Original was 25 cm long, 7 cm wide. Triangular piece on right-hand side is somewhat decomposed piece of cypress wood. Note difference in rooting density above and below wood and rooting continuing through wood.

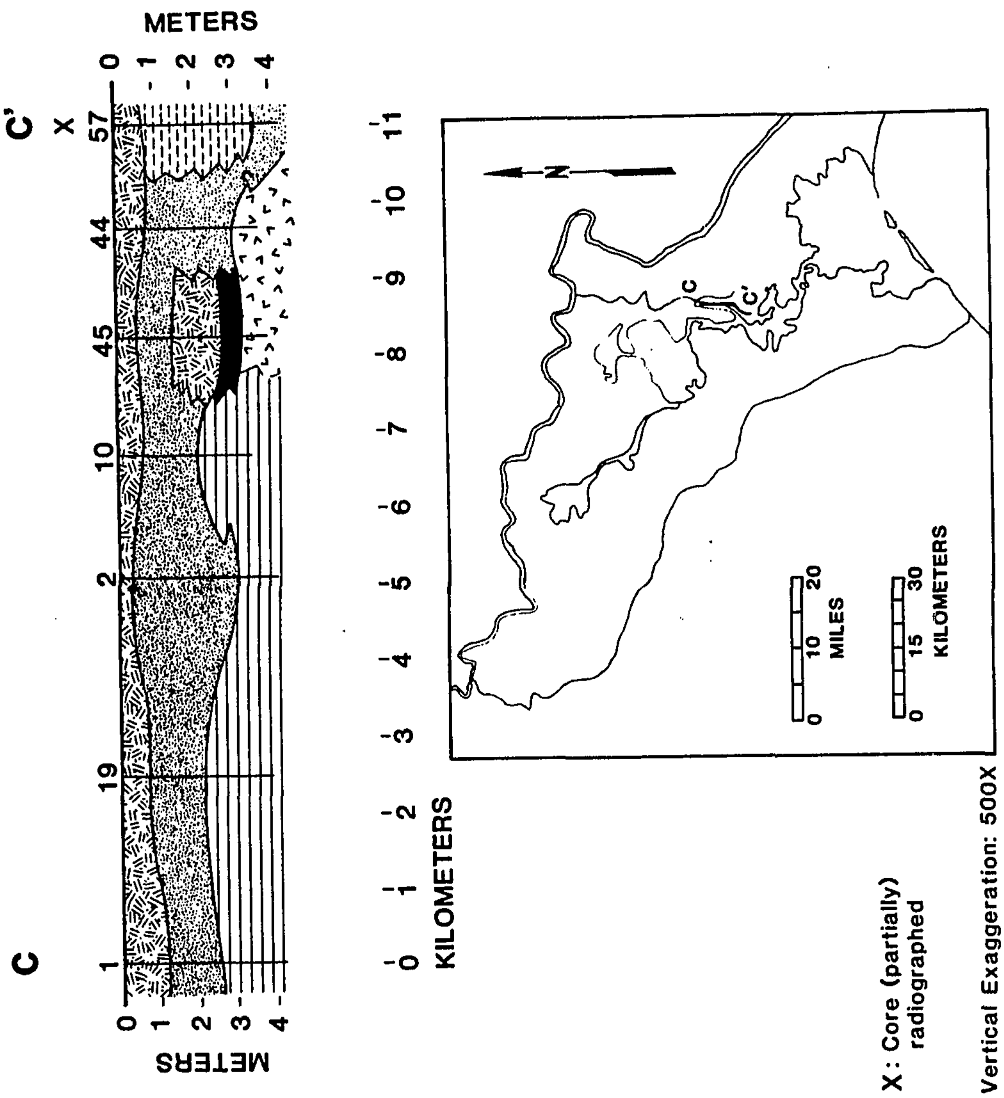
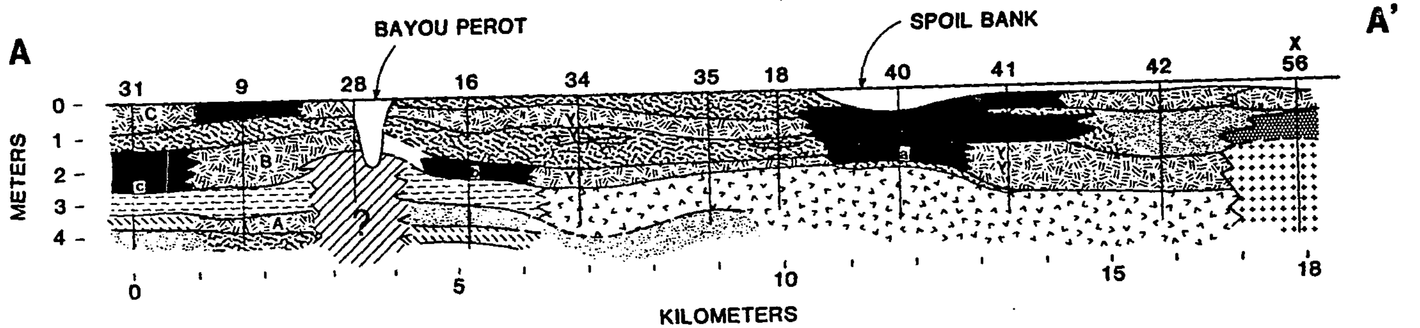
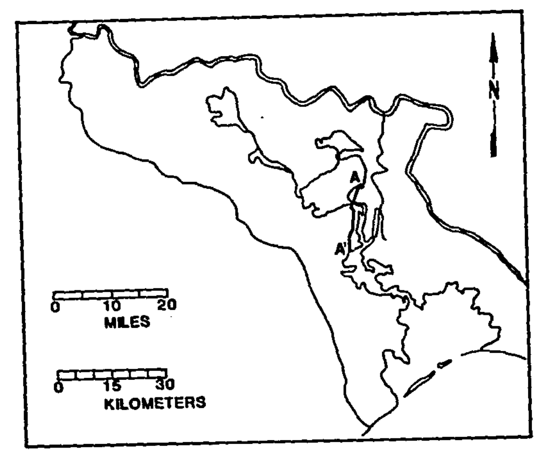


Figure 19 Barataria Basin - Stratigraphic dip-section C-C' (location and legend Figs. 12 and 13). This section is shown to illustrate extensive presence of incipient marshes (lithologic unit E-1

Figure 20 Barataria Basin - Stratigraphic dip-section A-A' (location and legend, Figs. 12 and 13). Three different organic-rich phases can be correlated laterally. Comparing stratigraphy with cross section B-B' (Fig. 28) (using cores BB 33, 14, 17, 47, 60, 65 and 43), cross section A-A' and B-B' correlate with each other.





C[14] DATES: Yrs. B. P.
a: 1920±80 (peat)
b: 1145±155 (peat)
c: 1565±75 (peat)

A, B, C } Organic-rich Phases

X: core (partially) radiographed
Y: wood

Vertical exaggeration: 500X

Figure 21 X-ray radiograph of abandonment phase (lithologic unit D), in BB 58, 100-125 cm depth (see Appendix for core log). Original is 25 cm long, 7 cm wide. Dark contact at top represents clay-peat contact. Note that clays are completely massive and featureless, except for evidence of plants. Note also that roots show up both white (diagenetically altered) and black (oxidized). Much of this diagenetic alteration appears to consist of pyrite.

<u>Organic lithologic units.</u>

Prior to discussing organic lithologic units, one should question whether it is correct to base environmental interpretations on the organic matter content of the material. Choosing break points in the range of organic matter at 5, 35, 75% is arbitrary (see Methods), but cross sections show that stratigraphic units emerge when using these limits, indicating that these boundaries have an ecologic meaning. The patterns become also clear when observing changes for every 10% organic matter. Ecological conditions become incorporated in the sediments because uniform surficial conditions will result in a characteristic vegetation. Consequently, preservation of organic material below the water table will be more or less uniform, resulting in strata of similar organic matter content. It may therefore be reasonable to correlate - with care - beds of similar organic quality, even though one could argue about the specific ranges used.

E - Organic-poor material.

Sedimentologic origin of organic-poor units is determined by interpretations from X-ray radiographs (Figs. 22 and 23). Since not all cores were completely X-ray radiographed, the depositional setting of organic-poor beds was only locally identified. X-ray radiographs are also useful for identifying diagenetic features. These are impossible to identify as specific minerals from radiographs alone. In reducing conditions, they are believed to consist frequently of pyrite (Coleman, 1966; Van Heerden and Roberts, 1980; Kosters and Bailey, 1983; Bailey and Kosters, 1983, A. Bailey, pers. commun.). Pyrite forms as a result of chemosynthesis in a reduced environment and is an indicator of stagnant, waterlogged conditions. Siderite is a similar indicator, but conditions are less reduced for siderite than for pyrite. For the formation of pyrite, SO_4^{2-} has to be reduced to S^{2-}. This reduction requires extremely reduced conditions (Patrick and DeLaune, 1977). Analyses of epoxy-mounted thin-sections made from samples from vibracores indicate that much pyrite is present as a replacement of plant fragments (Bailey and Blackson, 1984).

Organic-poor beds (15-35% organic matter) have several possible origins. They include well- and poorly-drained swamp deposits (Fisk, 1944; Coleman, 1966), incipient marshes and (vegetated) mudflats.

Mudflats are laterally restricted, subaerially exposed at low tide, and found locally in small bayous as far as 30 km inland. Because they are bordered by marshlands, they receive considerable detrital organic matter, and also contain algal mats. Shallow augering in these mudflats has revealed parallel lamination in dark colored muds with abundant organic detritus. Bioturbation was not observed but is difficult to assess in auger samples. Many of the organic-poor beds with abundant detrital organic matter originated in mudflats. Some were deposited as lacustrine sediments and are then closely related to unit C-4 (near shore basin fill and near shore lacustrine), but contain significantly higher amounts of organic matter. The unit is present in BB 64, 77, 91 and 95, and was laterally correlated only along cross section J-J' (Fig. 15). In cores taken in the lower basin, the unit was not as widely recognized, but cores in this area were generally shorter than the ones in the upper basin, preventing the unit from being properly recognized.

The difference between incipient marsh and organic-poor sediments with abundant organic remains is really one of matrix. The former have an organic matrix, interrupted by clay partings, whereas the latter have a clay-rich matrix, interrupted by beds of detrital plant remains.

"Incipient marsh" deposits originate close to levees and were particularly recognized along C-C' (Fig. 19), where levee clays with occasional rootlets and oxidation colors are blanketed by "incipient marsh" deposits consisting of organic-poor sediments with numerous clay lenses. This marsh deposit is interpreted as representing the period when Bayou Barataria was losing importance as a distributary [about 1000 yBP, Frazier (1967)], but was still occasionally flooding, thereby "choking" the vegetation and inhibiting the development of organic-rich marsh deposits. Frazier and Osanik (1969) recognized this phenomenon, although they called these organic-poor marsh deposits "peats", while noticing that they were commonly clayey. On top of the incipient marsh lies an organic-rich marsh, representing the last 700 years (Frazier, 1967) when Bayou Barataria ceased to experience extensive flooding, giving the marsh vegetation a better opportunity to accumulate organic-rich sediments.

F Organic-rich and peat beds.

Stratigraphic cross sections indicate that organic-rich and peat beds have similar environmental origin: peats and organic-rich beds always occur as part of the same stratigraphic unit. Because of ample coverage of this topic in the next xection (p. 97), only a short description will be given here.

The two main distinctions between peat and organic-rich material are: 1) degree of decomposition, and 2) the difference in organic matter and mineral content. Using the three categories of decomposition (see section on identification), it appears that organic-rich horizons are predominantly hemic, both in upper and lower basin. Peat beds are predominantly fibric in the upper basin and hemic in the lower basin. Sapric material was only observed in the lower basin, and often resembles "gyttja". Decomposition takes place under aerobic, or only slightly anaerobic conditions. Decomposition also causes loss of organic matter (Clymo, 1983). Thus, there is a positive correlation between the amount of organic matter and degree of decomposition. Organic-rich beds are thus "diluted" peats. The hypothetical cycle shown in Figure 24 describes marsh accretion and decomposition leading to incorporation of organic matter in various qualities in the subsurface. Eutrophic marshes become elevated above the water level through organic accumulation and clastic influx. Detrital influx may occur on two time scales: 1) 1-100 years (overbank flooding) and 2) 100-1000 years (delta lobe switching). If influx occurs on the larger scale, peats become completely blanketed. On the smaller scale, a slight increase in elevation is the result. A higher elevation causes increased decomposition, leading to loss of organic matter and increased aerobic oxidation (decomposition) and a decrease in elevation. After the marsh surface has subsided until just below the water level, the cycle can start again. The extent to which the cycle works depends on the quantities of above and below-ground biomass (root-to-shoot ratios (Raymond, 1986) that contribute to the peat. Organic-rich beds contain more mineral matter (ash) than peats, hence their detrital clastic influx is more voluminous, causing higher vertical accretion rates. Higher vertical accretion rates increase the likelihood that the here proposed eutrophic marsh cycle takes place. Renton et al. (1979) argue that slight changes in pH, for example after the passage of storms, may cause increased decomposition of organic matter, causing more hemic and higher ash beds to accumulate. Both processes may be effective, especially since lower Barataria Basin has frequent influx of marine water, affecting pH of the marsh. Burpbacher et al. (1973) established that the pH of surficial marsh soils frequently averages around 5. These authors did not study changes of pH with marine influence. X-ray radiographs of peats and organic-rich beds indicate various forms of diagenic or authigenic mineralization (Figs. 25 and 26). On X-ray radiographs, alterations are indicated by changes in matrix material, roots, or both. Both diagenetically altered and unaltered roots can be observed in a single radiograph. These relationships were recorded throughout the core. It is uncertain whether the presence of both altered and unaltered roots indicates a) a return to more oxidizing conditions or b) localized oxidation through roots and rhizomes. In the first case, alternating aerobic and anaerobic conditions may reflect the eutrophic marsh cycle and changing pH conditions.

Organic-rich and peat beds originated in arboreal swamps or associated with flotants. At times, abundance of wood fragments in peat horizons indicates that these were of a swamp origin. This was the case along the strike-oriented part of cross section H-H', and along the western portion of strike-section F-F' (Fig. 27). On the other hand, X-ray radiographs sometimes display essentially rootless peats (Figs. 25 and 26). One of these peats (BB 87, Fig. 25) was examined for pollen content and contained a high number of fern spores (R.E. McBride, pers. commun.). Presently, an environment in which ferns occur abundantly, is the floating marsh. Floating marshes experience fluctuating water tables to a lesser degree than rooted marshes, and are consequently not as much subject to decomposition. It is thought that flotants are good peat-forming environments. Along the dip-oriented portion of H-H' (Fig. 14) a peat horizon of extremely consistent quality and thickness extends over a large distance. Rootless peats and pollen analyses together indicate that this particular peat originated probably as a flotant. In addition, ^{14}C dates of peats along cross section H-H' indicate that peat formation continued for about 1000 years before a blanket of clay terminated accumulation (BB 84). Rooted marshes need more frequent influx of detrital clastics for nutrient supply (DeLaune et al., 1978). Paleobotanical analyses of paraffin-mounted microtomes indicated that organic-rich and peat beds in lower Barataria basin originated under fresh water conditions (Cohen, 1983).

Stratigraphy

This section will discuss general trends in the stratigraphy as observed along stratigraphic cross sections (Figs. 14, 15, 16, 19, 20 and 28), with exception of D-D'and E-E', which were only constructed as contoured cross sections (Kosters, 1983; this study) for the purpose of quantifying organic strata.

Open bay sediments:

The top of the open bay sediments in the lower portion of cross sections J-J' and H-H' (Figs. 14 and 15) is located at 6 m depth in both cores 82 and 87 (see Appendix for core logs), indicating that subsidence was even and differential compaction was negligible compared to overall subsidence, a conclusion also made by Coleman and Smith (1964) concerning Holocene strata in South Central Louisiana.

Towards the southern end of the study area, the top of the bay sequence appears at a much shallower depth of about 1.5 to 2 m (A-A' & B-B', Figs. 20 and 28). Whole, hinged, shells of Rangea cuneata in cores BB 25 and BB 55 date 2500 - 3000 yrs BP respectively, only slightly younger than those in the upper basin. This shallow occurrence of the bay unit indicates that clastic influx in the central basin was more voluminous than in the upper basin.

Fine-grained parallel laminated strata:

Interdistributary basin-fill sediments are most clearly distinguished along cross section H-H' (Fig. 14), where they are about 2 to 3 m thick. They were not as easily distinguishable in the lower basin, because cores taken in that area were shallower.

Organic-rich sediments and peats:

The deepest occurrence of organic-rich material and peat is about 2-3 m in the upper and 3-4 m in the lower basin. Peat lenses are rare and discontinuous in the lower basin and more continuous in the upper basin (cf. dip section A-A' and H-H', Figs. 20 and 14). Peats occur always as part of an organic-rich bed and tend to be predominantly located on top of organic-poor deposits or on non-organic clay (see p. 70). A gradual upward increase in organic matter (e.g., an upward sequence of detrital clastics, organic-poor sediments, organic-rich sediments, peat) occurs less frequently than an abrupt increase. Along H-H' (Fig. 14), a gradual upwards increase occurs only in the western (strike-oriented) part of the section. Along J-J' (Fig. 15), both a gradual and an abrupt increase can be noted. In sections through the lower basin, a gradual upwards increase in organic matter seems to occur more frequently than an abrupt increase.

Paleobotanical analyses from paraffin-mounted thin-sections taken from vibracore samples indicate that most organic-rich and peat beds originated in grass- and sedge-type marshes.

Fine-grained clastics and organic-poor sediments:

A 24 km-long organic-poor lens is visible in the upper portion of cross section F-F' (Fig. 27) and represents a basin-wide flooding event. Several detrital clastic lenses are visible within this unit, which can be found throughout the basin, but is locally absent (BB 5). Along H-H' (Fig. 14), the flooding event is represented by a massive clay lens.

Stratigraphic variation within organic beds

Peat accumulated in parts of the basin that experienced the least detrital influx, being furthest away from natural levees and basin drainage channels. Near surface sediments are mostly composed of organic-rich material and not of peat. Generally, one to two (upper basin) or two to three (lower basin) organic-rich phases can be recognized along cross sections. Along the southern portion of H-H' (Fig. 14), peats of phase B split into a lower (phase A) and a central (phase B) organic-rich bed. With respect to this phenomenon, it is important to realize that Fisk (1944) placed the "Lake Borgne Fault zone" in a NW-SE direction parallel to the shorelines of Lake Salvador. He claimed that the fault zone has a direct influence on the shape of the lakes and alignment of streams in the deltaic plain, and on the location of major depocenters. Thus, evidence of the fault zone is probably also seen in the increase from two to three organic beds. An increase in the rate of subsidence probably took place along this fault zone.

Development of Barataria Basin

Data and interpretations by Fisk (1944), Frazier (1967), Kolb and Van Lopik (1958) and Weinstein and Gagliano (1984), complemented with the results from this study, delineated in detail in the previous paragraphs, indicate that, about 4000 years before present (BP), Barataria Basin existed mainly as a brackish delta flank bay east of the Maringouin/Teche Delta system (Figs. 29 and 30A). Rangea cuneata thrived in this bay. When sedimentation in lobes 6, Bayou Terrebonne, and 7, Bayou des Familles, (lobe numbers from Frazier, 1967) became prominent, the basin began to be filled by overbank flooding (Fig. 30B). During this time, a basin drainage channel became established. Its levees provided a substrate on which a marsh developed (locally present organic-rich phase A, see cross-section A-A', Fig. 20). After active clastic deltaic sedimentation had shifted further east, organic-rich phase B developed (cross-section B-B' Fig. 28) around 2000 yrs BP. This phase coincides with the Tchula and Marksville periods (Weinstein and Gagliano (1984). Averaged ^{14}C ages for bottoms of peats in the upper (North of Lake Salvador) and lower (South of Lake Salvador) basin, indicate that peat accumulation migrated southward: in the upper basin, accumulation started around 2250 yrs BP while in the lower basin, it was initiated around 1650 yrs BP. Around 2000 BP, the lower basin was probably still partially open and being filled with overbank sediments. Around 800 yrs BP, terrigenous sedimentation in the early Lafourche Delta complex caused the peat swamps to become blanketed with sediments from overbank flooding (Fig. 30D). This interruption of phase B can be seen in almost every core in the basin, but is locally absent. It is represented by a 10 to 50 cm thick lens of material that consists usually of clay-sized sediment, but is occasionally slightly coarser grained. This detrital event correlates with the Baytown period (Weinstein and Gagliano, 1984) and lasted until about 500 yrs BP, when late Lafourche and Plaquemine/Modern Delta outbuilding shifted the major depocenters southward and the most recent peat accumulation phase started (organic-rich phase C, Fig. 20). This phase continued until very recently: during the last 100-50 years, diversion of deltaic sedimentation to the West (Atchafalaya system) (Fisk, 1952; Van Heerden and Roberts, 1982) has decreased longshore sediment transport and increased shoreline erosion. Consequently, increased salt-water intrusion is taking place, leading to a decrease in organic matter production further updip into the basin.

Additional changes in botanical character may have taken place. Jesuit Du Pratt (1776, in Russell, 1936) noted that the swamps of South Louisiana consist largely of tree ferns and <u>Equisetum</u> (horsetails). Although these plants exist today, they are not the principal components of the swamp community (Sasser et al., 1983). Secondly, Bayou Lafourche was closed off from the Mississippi River in 1904 (Weinstein and Gagliano, 1984), thus halting the influx of detrital clastics. These two events were probably important additional factors for today's decreased subsurface organic matter preservation.

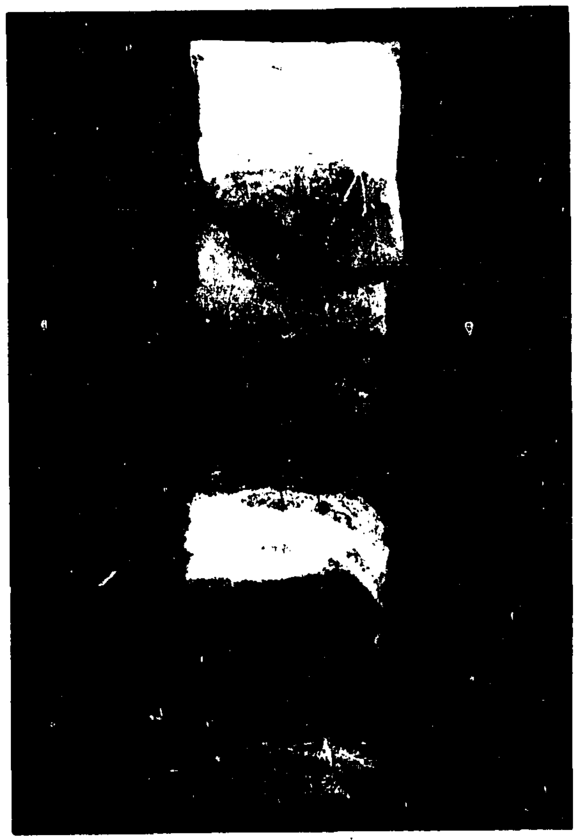


Figure 22 X-ray radiograph of organic-poor material (lithologic unit) in BB 58, 75-100 cm depth. Original is 25 cm long, 7 cm wide. Root density and diagenetic features are moderately abundant. Some roots are diagenetically altered, most likely by pyrite.

Figure 23 X-ray radiograph of organic-poor material (lithologic unit) in BB 62, 26-44 cm depth. Original is 25 cm long, 7 cm wide. Root density decreases towards top (organic-rich unit) but is high in organic-poor unit. Very little diagenetic alteration can be observed, indicating that conditions did not become extremely anaerobic. Most diagenetic alteration can be observed as small dots, not as root replacements. Clay lens in central portion is associated with marsh drowning event of Figure 30-D/E (cf. Fig. 22).

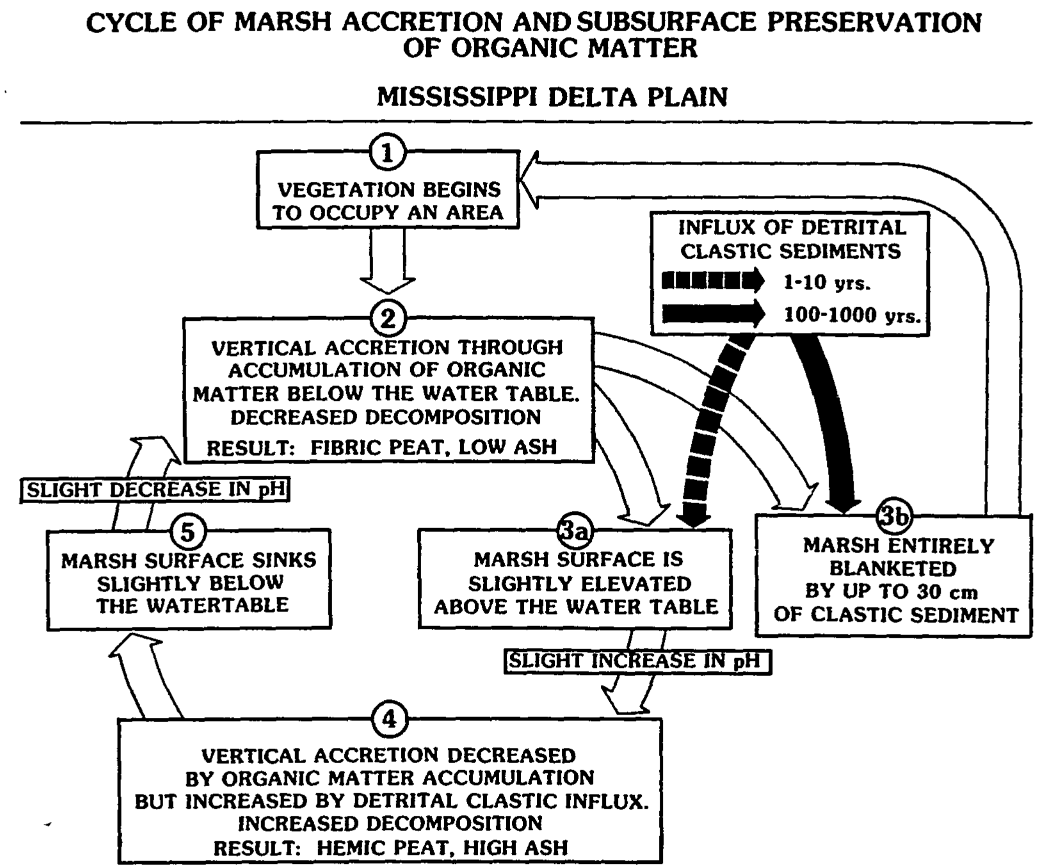


Figure 24 Hypothetical cycle of vertical marsh accretion, decomposition and subsurface organic matter preservation in the Mississippi Delta Plain.

Figure 25 X-ray radiograph of organic-rich material (lithologic unit) in core BB 87, 50-75 cm depth. Original was 25 cm long, 7 cm wide. Whitish flakes are aluminum from core barrel. Note near absence of roots and diagenetic features, and abundance of freshwater sponge spicules just below center. This rootless bed of organic-rich material may have been associated with a floating marsh.

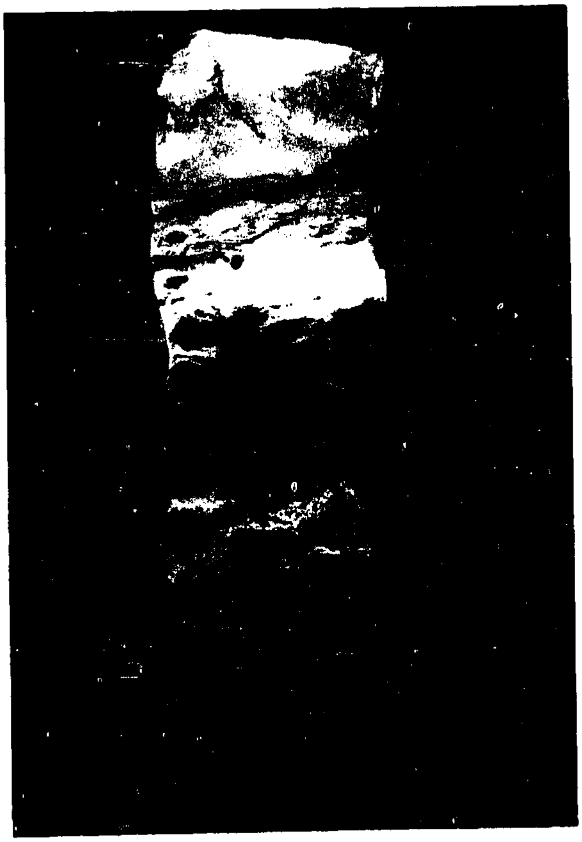
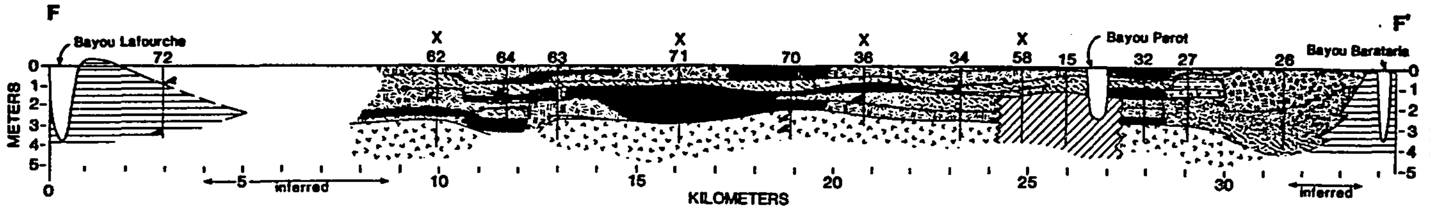


Figure 26 X-ray radiograph of peat (lithologic unit) and overlying silty sandy lens in BB 36, 75-100 cm depth. Original was 25 cm long, 7 cm wide. Note rip-up of peat into overlying silt and rootlessness of peat overall. Some fresh water sponge spicules can be seen in bottom of picture. Very thin clay lenses in peat may have been deposited by flocculation after slight change in pH of water, for example after passage of major storm.

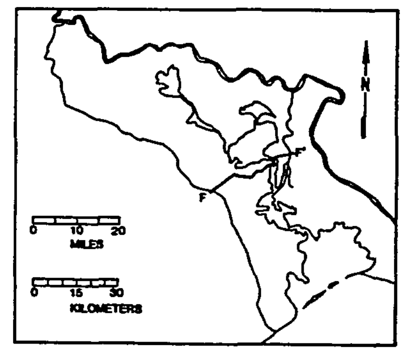
Figure 27 Barataria Basin - Stratigraphic strike-section F-F' (for location and legend see Figs. 12 and 13). Note that more peat is present in the western basin than in the eastern basin, and that the upper organic-poor phase contains detrital clastics in BB 36 and 27.



C14 DATES Yrs. B.P.

a: 1980 ± 135

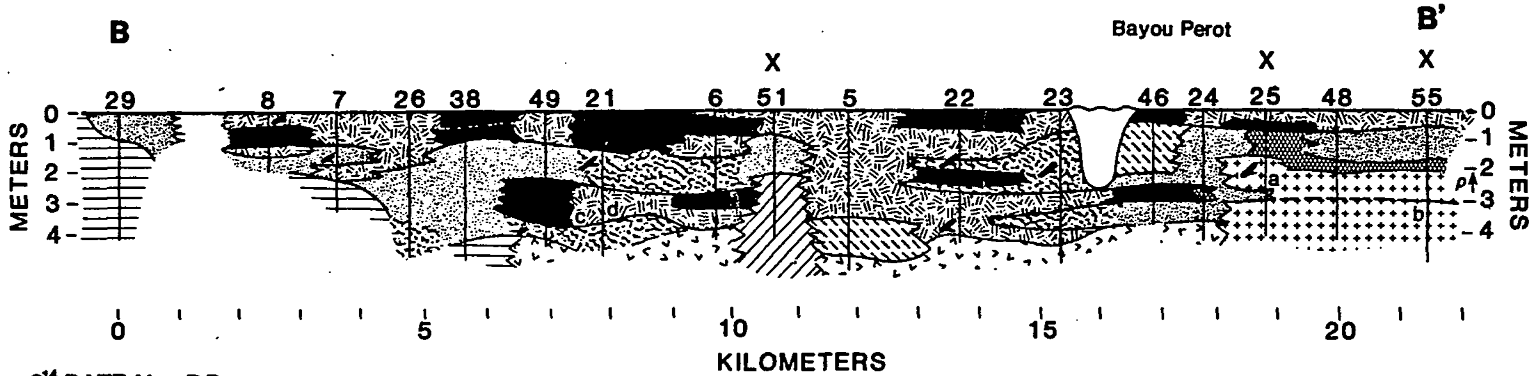
b: 1110 ± 75



: Wood

Vertical exaggeration: 500X

Figure 28 Barataria Basin - Stratigraphic dip-section B-B' (location and legend, Figs. 12 and 13). Note more erratic appearance of organic fill in this section than in cross section A-A' (Fig. 20).



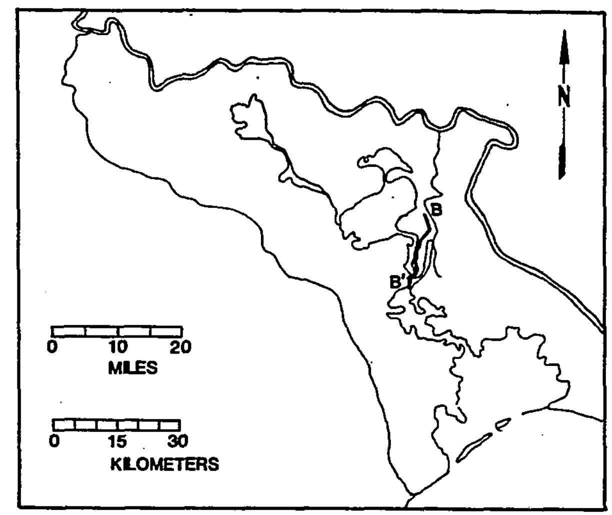
C[14] DATE Yrs. B.P.

a: 2545 ± 60 B.P.

b: 3050 ± 120 B.P.

c: 2060 ± 300 B.P.

d: in BB 13 at a same depth as bottom of organic rich material in BB 21 1565 ± 75 B.P.



In this particular x-section, ⬚ may actually be ▩ since the coves were fairly shallow.

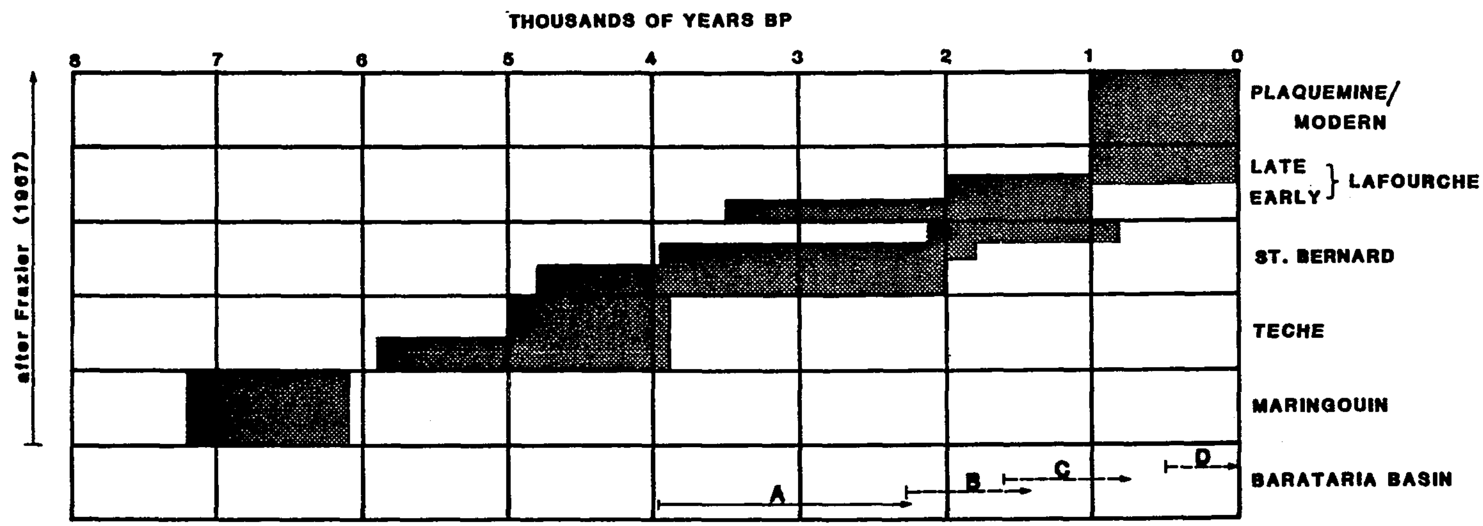
p: Possibly basin-fill

Wood

X: Core (partially) radiographed

Vertical exaggeration: 500X

Figure 29 Chronology of Mississippi Deltaic Complexes (after Frazier, 1967) and major sedimentary events in Barataria Basin, based on the stratigraphy and on ^{14}C dates of whole, hinged Rangea cuneata shells, in-situ peat horizons (Fig. 30 Paleogeographic reconstruction).



A Barataria Basin – open bay and basin fill.
B First period of peat accumulation.
C Peat accumulation interrupted.
D Second period of peat accumulation.

Figure 30 Paleogeographic reconstruction of Barataria Basin based on data from Frazier (1967) and from this study.

A - 4000 yrs BP. Barataria Basin is a large open bay, between the Maringouin/Teche and early St. Bernard delta complexes. Rangea cuneata thrives in this bay.

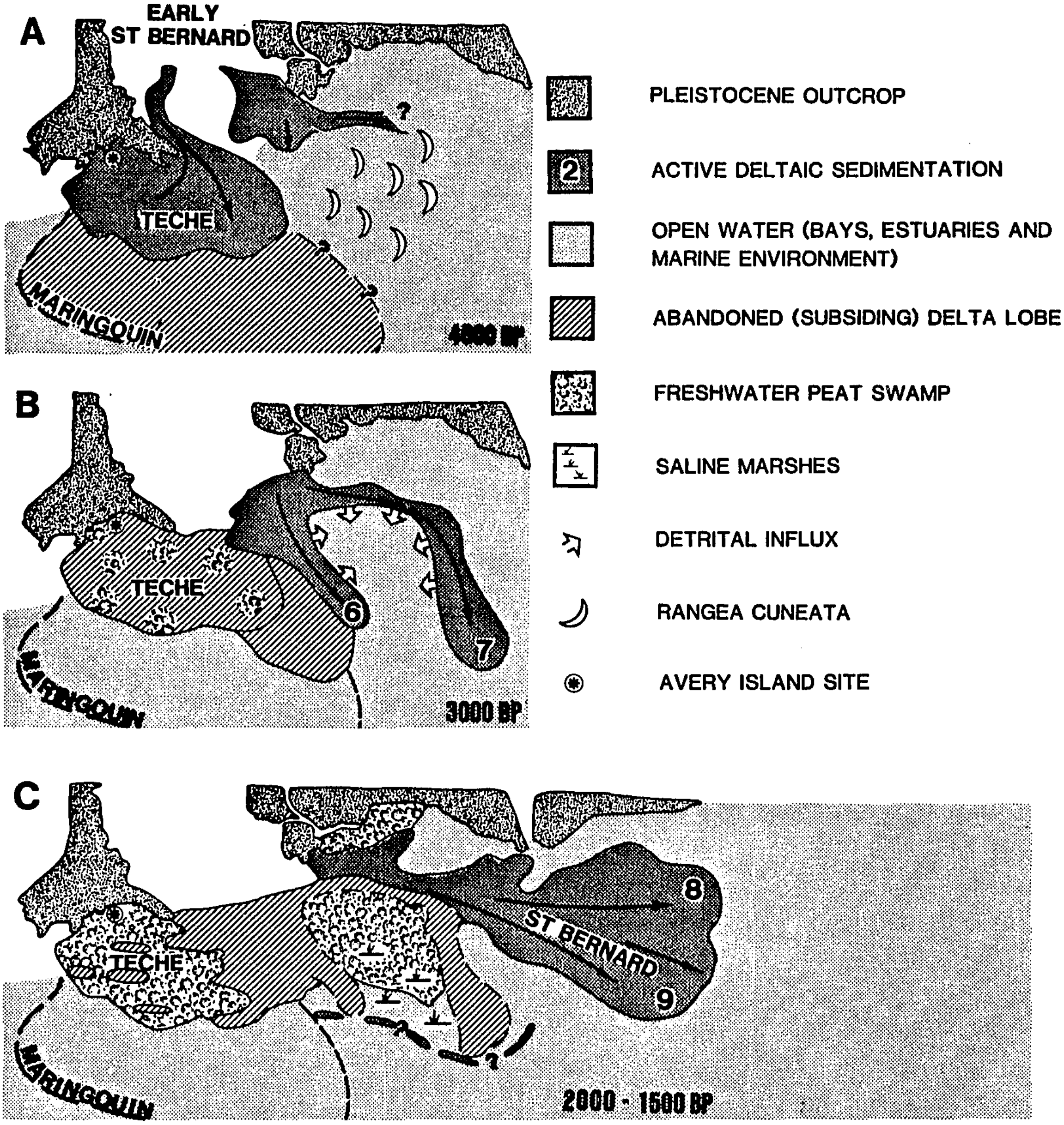
B - 3000 yrs BP. lobes #6 and #7 (Bayou des Families) are dominant. Barataria Basin is filled by overbank sediments. Peat phase A locally developed.

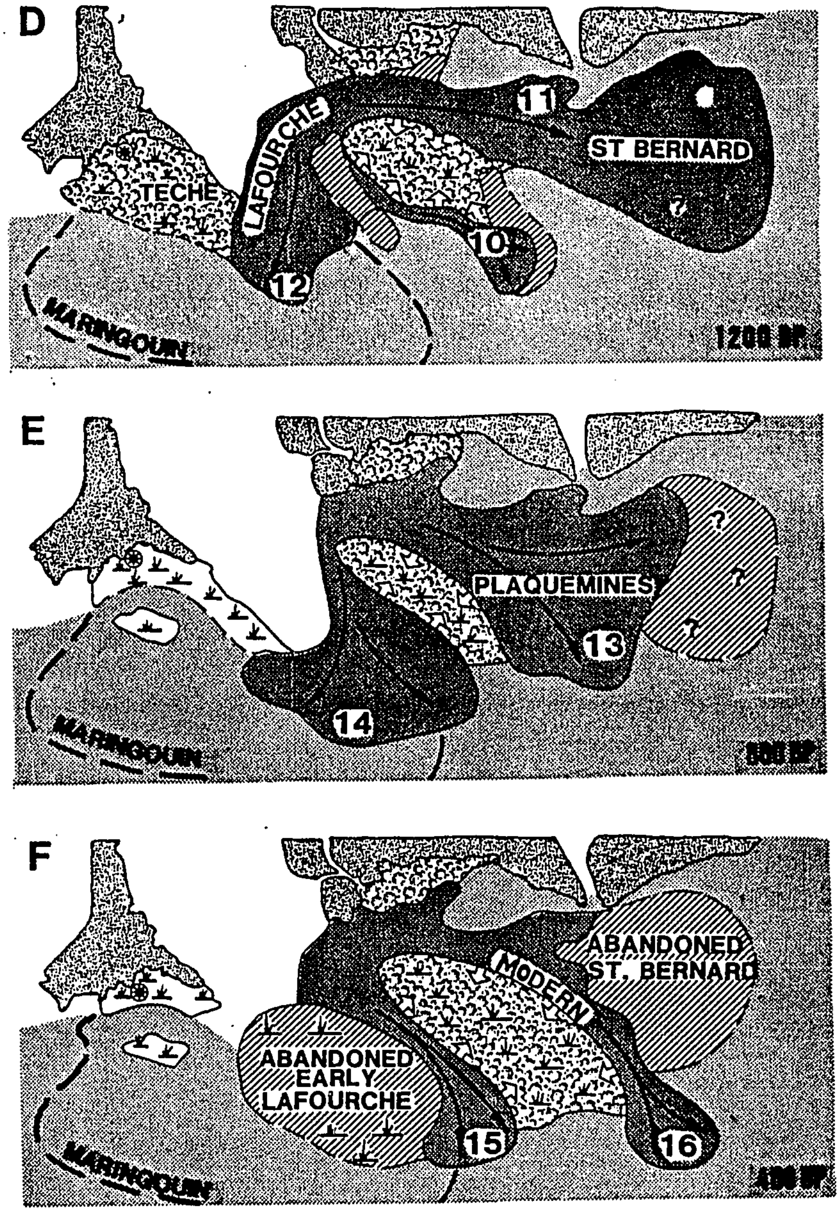
C - 2000 yrs BP. Lobes 6 and 7 have been abandoned and an ideal sheltered peat-forming environment exists (organic-rich and peat phase B).

D - 1000 yrs BP. Sedimentation from the Lafourche complex causes increased detrital influx in Barataria Basin, more or less terminating organic-rich phase B.

E - 800 yrs BP. Peat swamps are everywhere blanketed by clastic sediment, but this is locally absent.

F - 400 yrs BP. Clastic deltaic sedimentation has bypassed the area and renewed peat accumulation starts (phase C).


A
EARLY
ST BERNARD
TECHE
MARINGOUIN
4000 BP
B
TECHE
MARINGOUIN
3000 BP
C
TECHE
ST BERNARD
MARINGOUIN
2000 - 1500 BP
PLEISTOCENE OUTCROP
ACTIVE DELTAIC SEDIMENTATION
OPEN WATER (BAYS, ESTUARIES AND MARINE ENVIRONMENT)
ABANDONED (SUBSIDING) DELTA LOBE
FRESHWATER PEAT SWAMP
SALINE MARSHES
DETRITAL INFLUX
RANGEA CUNEATA
AVERY ISLAND SITE


D
LAFOURCHE
ST BERNARD
TECHE
11
10
12
?
MARINGOUIN
E
PLAQUEMINES
13
14
MARINGOUIN
F
ABANDONED
ST. BERNARD
MODERN
ABANDONED
EARLY
LAFOURCHE
15
16
MARINGOUIN

ANALYTICAL RESULTS

Distribution of organic matter

This section will address the spatial and statistical variations in organic matter content. In addition, implications for modern coal-forming environments will be discussed.

Figure 31 is a histogram of the organic matter content of 789 samples. The only significant breakpoint in the curve occurs at 85% organic matter. The break at 10% organic matter is artificial and caused by consistent sampling and analyzing of the beds below the peat. Fifty percent organic matter divides 5.1-5.5% occurrences and is statistically insignificant. The breakpoint at 15% is based on a breakpoint of the Soil Conservation Service (1971). The break at 35% organic matter is based on data from Farnham and Finney (1965).

Average organic matter content for peat (i.e., for that material containing more than 75% organic matter by dry weight) is 81.27% for all areas and ranges from 79.93% to 83.87% for individual areas (Fig. 32, Table I). Thus, the average quality difference between peats that originated in fresh water forested swamps and herbaceous marshes is negligible. One should also note that there is virtually no difference between the quality of peats in the marine-influenced area of Avery Island and those that have never experienced salt-water intrusion, Lake Pontchartrain and upper Barataria Basin. The latter area is the one with the highest mean organic matter content for true peats, but it should be noted that standard deviation and variance are slightly higher than in lower Barataria Basin (Table I). One sample with 93.36% organic matter in upper Barataria Basin influenced the variance and standard deviation.

In general, the ash values of Mississippi Delta peats are high by Northern Hemisphere standards, but are comparable with the somewhat higher inorganic content of many Southern Hemisphere coals (Stach, et al., 1975).

Quantification of various types of organic sediments

In order to calculate quantities of sediments in the subsurface, isopach techniques are commonly used. This technique could not be applied in Barataria Basin, either because of the erratic nature of the beds, or, as in upper Barataria Basin, because of a lack of sufficient strike sections. Therefore, a different technique was developed: along each of 7 cross sections, the organic matter content of each sample was plotted at the midpoint of the sample interval. Cross sections were then contoured at 10% organic matter intervals (Fig. 33). These intervals were grouped into 4 ranges: 0-10% (detrital sediments), 10-30% (organic-poor material), 30-70% (organic-rich material), 70--100% (peat). Then, each of these four ranges is planimetered using a LASICO™ digital planimeter and the surface area of each range was calculated and expressed as a percentage of the total surface area of the cross section for the upper 4.5 m.

The results of this technique are shown in Table II and Figures 34, 35, and 36, and indicate the following relationships. First, cumulative percent occurrence of detrital and organic-poor sediments is about 50% each (Table II), and mean occurrences of detrital sediments, organic-poor material, and peat all show a low standard deviation. Secondly, with the exception of cross section D-D', a) the quantity of organic-rich material increases with decreasing amounts of peat (r=0.75); b) amounts of organic-poor material increase with amounts of peat; c) the quantities of detrital sediments and organic-poor material decrease with increasing amounts of organic-rich material (r=-0.69 and -0.75). The high correlation coefficients suggest an ecologic relationship between quantities of these different organic sediment types, even though the types themselves seem to be somewhat arbitrary, as explained at the beginning of this section. From stratigraphy alone, it appeared that peat beds occur as parts of organic-rich horizons, and this strong correlation confirms that relationship. Organic-rich material and peat are similar in terms of their depositional setting, since the increase of one correlates positively with the decrease of the other. Admittedly, these figures are here applied to a continuously variable system, which may not be totally correct. A hypothesis could be formulated based on both stratigraphy and organic matter variability (see also Fig. 24): at some point in time, conditions are such that initial accumulation of organic-rich material can take place. Later, a slight change, i.e., an "improvement" in conditions sets the stage for the accumulation of peat. This improvement finds its origin in two processes, as was suggested in Figure 24:

1) a decrease in detrital clastic influx, lowering the ash content of the organic-rich material and turning it into peat;
2) a decrease in pH, diminishing decomposition of organic material (Renton et al., 1979).

The first process has been documented here, the second one can only be implied, since pH measurements were not carried out. Brupbacher et al. (1973) noticed that pH varied between 4.5 and 7.5 in surficial marsh sediments of the deltaic plain. There is probably a feedback mechanism connecting both processes. This feedback mechanism is depicted in Fig. 24. Kaiser (pers. commun.) has postulated that clay-sized sediments may form a hydraulically necessary parameter in peat formation in that such clays may exist as a discharge point for groundwater, thus creating necessary wet conditions. In addition, strong positive correlations between quantities of peat and organic-poor material ($r = 0.75$) indicate that a flooding event (yielding organic-poor sediment), such as may occur after delta lobe switching, can have a beneficial effect on future peat accumulation, while absence of a flooding event yields only organic-rich material ($r=-0.76$). On the other hand, it can also be implied that peat-forming environments eventually form topographic lows which are likely to become flooded.

Although the total amount of organic-rich material and true peat together is about 50% of the cross sectional surface area in both upper and central basin, significant differences exist between occurrences of both types on the updip and downdip side of Lake Salvador (Table II; Fig. 34). More true peat occurs in the upper and western than in the central and southeastern basin. In other words, "dilution" by detrital clastic sediment influx (suspended clays in flood waters) was more frequent in the lower than in the upper basin. Two factors may be related to this observation: 1) difference in depth of the organic-filled depression between the upper (2-3 m) and central (3-4 m) basin; this difference may be related to the Lake Borgne fault-zone; 2) proximity to marine influence and tidal flushing in the lower basin.

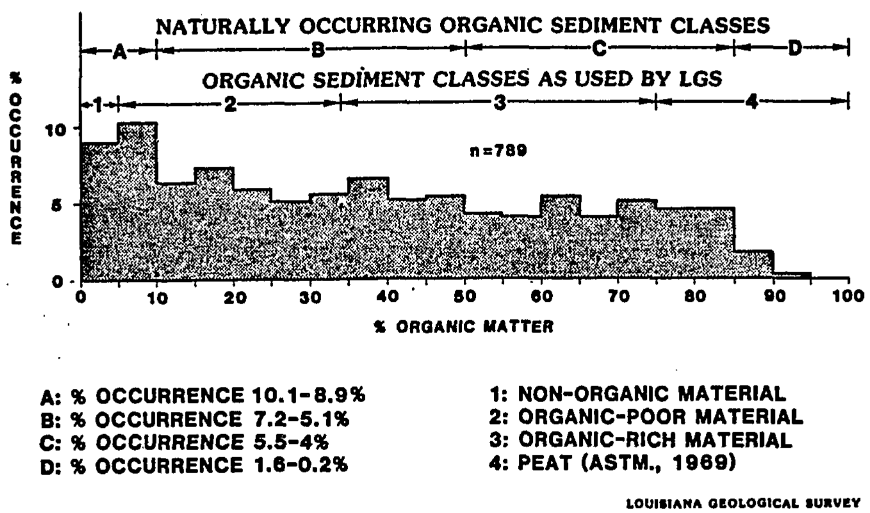


Figure 31 Histogram showing the frequency of occurrence of the organic matter contents (in 5% ranges) of 789 samples, taken from all study areas. Natural breaks in the histogram are either nonexistent or statistically insignificant.

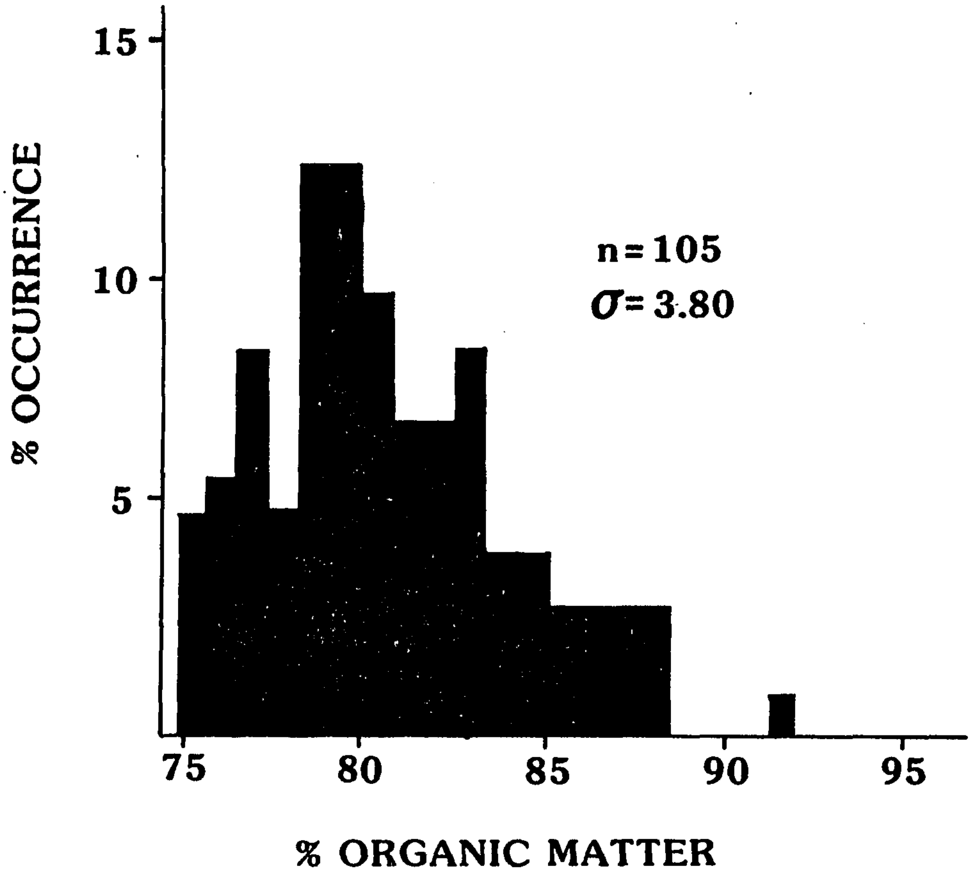


Figure 32 Distribution curve of the quality of peat samples in all areas. Vertical axis: ranges of organic matter content; horizontal axis: % frequency of occurrence.

TABLE I - Average properties of peats for different study areas (Fig. 31 and 32).

Area	No. of Samples	Range of Organic Matter	Mean	Std.Dev.	Var.
All	105	74.90 - 93.36	81.27	3.80	14.45
UBB	28	75.25 - 93.36	83.87	4.23	17.89
LBB	44	74.90 - 84.64	79.73	2.47	6.14
G	9	75.75 - 87.80	80.94	3.98	15.84
AI	7	78.83 - 85.81	81.41	2.52	6.38
LP	17	75.13 - 88.71	81.13	4.29	18.47

All: all areas

UBB: Upper Barataria Basin

LBB: Lower Barataria Basin

G: Gueydan

AI: Avery Island

LP: Lake Pontchartrain

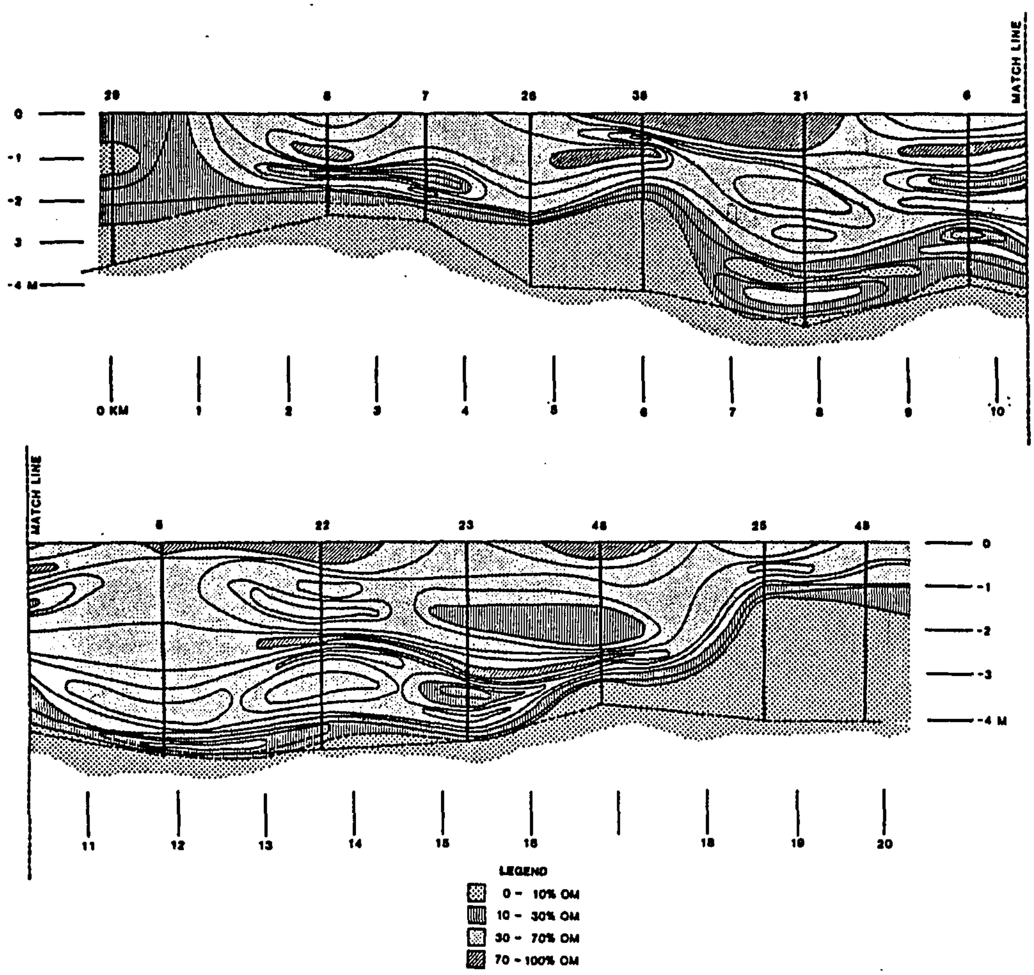
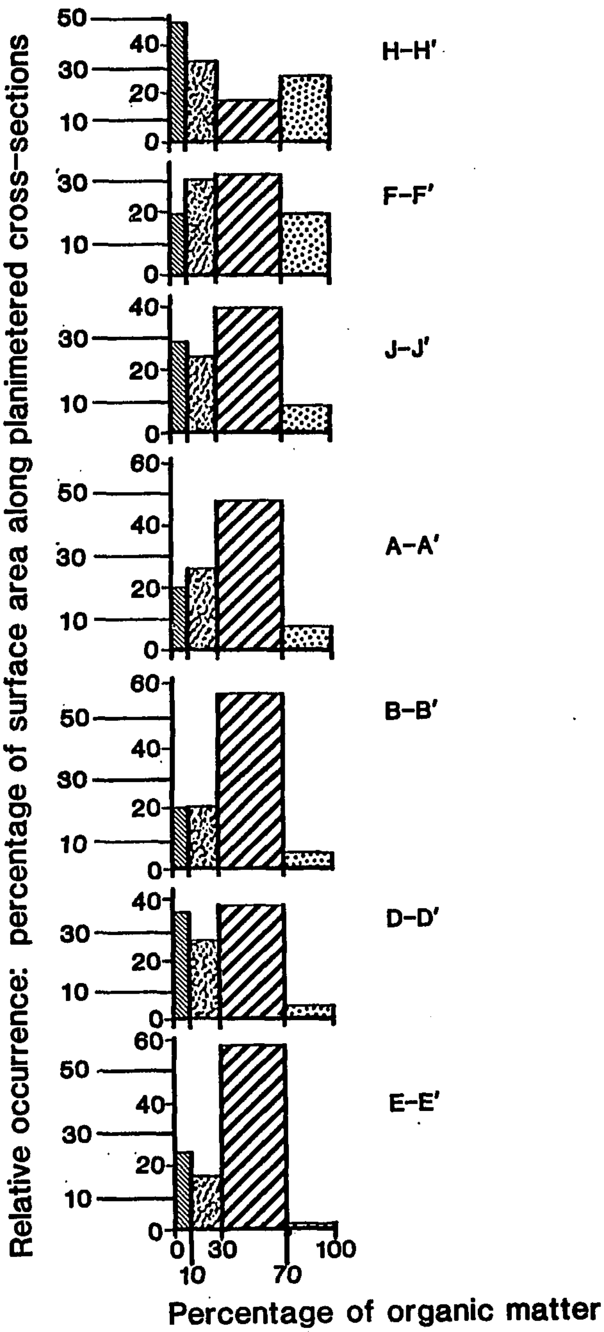


Figure 33 Barataria Basin: contoured dip-section B-B'. Contour lines were drawn at 10% organic matter intervals. The surface area of each of four ranges was calculated using a digital planimeter (Fig. 34).

Figure 34 Barataria Basin: histograms showing the proportion of surface areas of the four ranges of organic matter as determined from 8 planimeter cross sections. Vertical axes: % occurrence; horizontal axes: organic matter content (four ranges: 0-10%; 10-30%; 30-70%; 70-100%).


Relative occurrence: percentage of surface area along planimetered cross-sections
H–H'
F–F'
J–J'
A–A'
B–B'
D–D'
E–E'
0
10
30
70
100
Percentage of organic matter

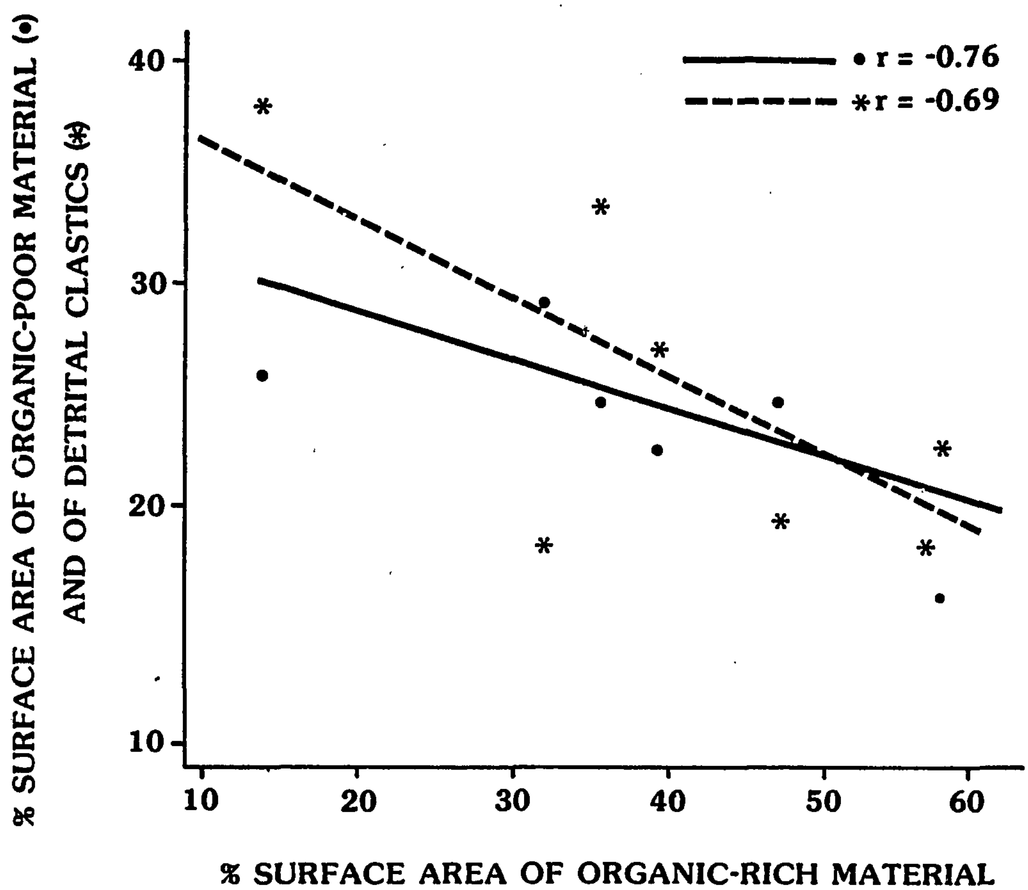


Figure 35 Linear regression and correlation between surface areas of organic-poor material and detrital sediments, respectively (Y-axis) and organic-rich material (X-axis). With increasing amounts of organic-rich material, quantities of detrital sediments and organic-poor material decrease (r=-0.69 and r=-0.76, respectively).

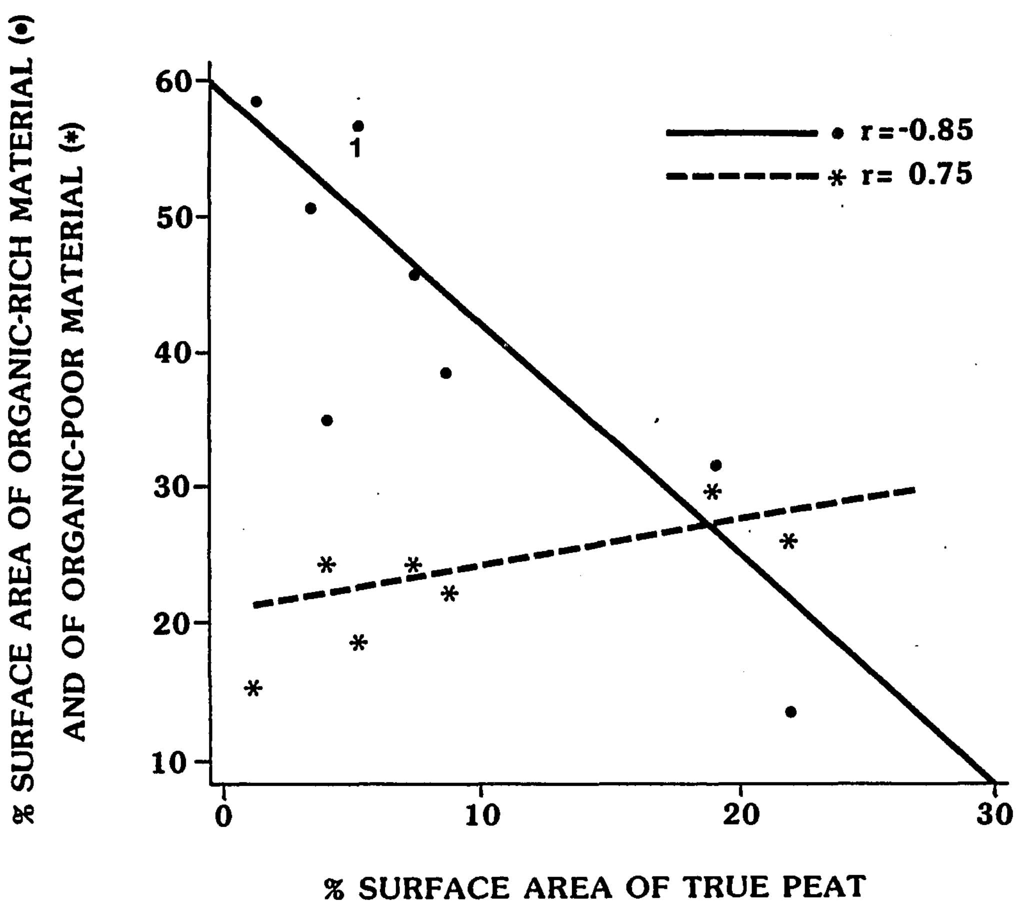


Figure 36 Linear regression and correlation between surface areas of organic-poor and organic-rich material, respectively (Y-axis) and peat (X-axis). With increasing amounts of peat, organic-rich material decreases (r=-0.85) and organic-poor material increases (r=0.75).

TABLE II - Percent surface area of the 4 organic sediment types in Barataria Basin. Surface areas were determined by planimetering contoured cross sections (Fig. 33 and 34).

Cross	I Detr. 0-10% om[1]	II Organic-poor 10-30% om	III Organic-Rich 30-70% om	IV Peat >70% om
A-A'	19.70	24.25	47.35	7.50
B-B'	19.12	19.25	56.73	4.91
D-D'	34.15	25.61	36.28	3.96
E-E'	23.88	16.96	58.26	0.89
F-F'	19.17	29.95	31.84	19.06
H-H'	38.08	26.47	13.62	21.83
J-J'	28.14	23.86	39.57	8.43
mean	26.03	23.93	40.52	9.5
std.dev.	7.69	4.44	15.50	7.89
variance	59.18	19.71	240.32	62.40
Total average occurrence of I + II and III + V (%)	50.11		49.89	

[1] organic matter

TABLE III - Correlation matrix for surface areas of different types of organic material (Figs. 33 and 34).

	DETR	OP	OR
OP	0.19		
OR	-0.69	-0.76	
P	0.27	0.75	-0.85

LEGEND

DETR: Detrital clastic sediments

OP: Organic-poor sediments

OR: Organic-rich sediments

P: Peat

Implications for modern coal-forming environments

What causes peats in the Mississippi Delta to contain an average of only 81.27% organic matter ? Is the organic matter content of peat similar to that found in the eventual coal? In other words, does peat-to-coal transformation significantly influence the inorganic component?

The bulk of the inorganic component of Mississippi Delta Peats consists of authigenic (plants), biogenic (fresh water sponges) and detrital silica, diagenetic minerals (pyrite, siderite) and water-soluble salts. Of these, biogenic silica and water-soluble salts are generally not found in coal (Bailey and Kosters, 1983; Kosters and Bailey, 1983; 1986) and these may thus disappear during early diagenesis, possibly by natural leaching. A leaching experiment (Kosters and Bailey, 1986) showed:

1) higher quantities of more water-soluble salts occur in peats than in organic-rich material; this trend becomes exponentially less valid with decreasing organic matter content.

2) an average of 1/3 of the ash could leach, resulting in overall higher quality peats and eventual coals. Thus, reducing the ash content by 1/3 from 18 to about 13%, coals resulting from Mississippi Delta peats could contain an average of 87% or more organic matter.

In addition, some biogenic silica probably disappears in the process too (Bailey and Kosters, 1983; Andrejko et al., 1983). Since the inorganic component of undecomposed plants may range from 87-99% (Alexander; 1977), a better quality coal may form than is suggested by the organic matter content of these peats. Vegetative communities in the Mississippi Delta may contain close to 13% biogenic inorganic material. A reassessed organic matter content of 87% (Kosters and Bailey, 1986) could thus reflect the original inorganic composition in the vegetative matter. Therefore, the contention by Cecil et al. (1985) that only oligotrophic bogs can form material of good pre-coal quality may need reevaluation.

Accretion rates, compaction, subsidence.

Vertical marsh accretion rates

Depending on the quantity of detrital influx and the amounts of submergence, South Louisiana marshes accrete through the accumulation of both mineral sediment and organic material, but the relative contributions of each are presently unknown (Delaune et al, 1983; 1984; Hatton et al, 1983, Fig. 24). Marshes receiving large quantities of detrital clastics accrete at higher rates than those that do not. This has been verified by numerous researchers and in Louisiana by DeLaune et al. (1978; 1984) and Baumann (1980). Reported values for vertical marsh accretion range from 0.40 to 1.91 cm/yr with an average of 0.69 cm/yr and lack any clear trends, except for streamside/inland differences. It is unclear from the literature whether fresh marsh accretion rates differ from those of salt marshes. It is generally assumed that salt marshes receive more detrital clastic sediments than fresh marshes, due to storms (Saxena, 1976), cold fronts, or hurricanes (Baumann, 1980). Present conditions are not optimal for determining such differences: artificial levees have altered normal accretion rates.

Stratigraphy and ^{14}C dates for peats in upper Barataria Basin, result in average accretion rates for different types of sediment as summarized on the BB 84 core log (App. A). A ^{137}Cs dating analysis was run on the same core. The average accretion rate since 1963 was about 0.9 cm/yr for an organic-poor bed with 30% organic matter. ^{14}C dating indicated that an accretion rate of only 0.1 cm/yr. The latter number has a larger error than the former because of the difference in time scale used. Thus, a considerable change has taken place between the surface and subsurface. The sediment has become compacted, but this well-documented phenomenon has also been attributed to loss of material (Clymo, 1983; 1986, pers. commun.). The underlying peat bed appears to have accumulated at a rate of about 0.04 cm/yr. This number may be rather low, possibly typical for flotant peats. Note that this peat existed for a time period of about 1000 years, without any noticeable detrital clastic influx (less than 25% ash). Surface accretion rates for this peat could be about 0.4 cm/yr, assuming a tenfold loss of material (Clymo, 1983), a value that would be deemed insufficient by DeLaune et al. (1978; 1983) for maintaining the marsh surface at the water level, taking into account that sea level is presently rising. These values are thought to add additional support to the interpretation that these peats were of a flotant origin. Peat accretion rates measured in the subsurface in the lower basin are more difficult to determine, because of a lack of sufficient ^{14}C dates. Rates appear to be on the order of 0.8 cm/yr, a value also reported by Frazier et al. (1978). If surface compaction or loss of material can be assumed to amount to ten times the original thickness, then one arrives at surface accretion rates of 0.4-0.8 cm/yr for peats. These values are within the range of values reported by DeLaune et al. (1978; 1983) and also coincide with other rates by Frazier et al. (1978).

Bulk density and Sediment Compaction

Values for bulk density can help explain the compactional behavior of organic sediments during the first few thousand years after accumulation.

Fifty-nine bulk density measurements were made: bulk density ranged from 0.07 to 0.20 g/cm^3, and appeared to be unrelated to organic matter content, an observation also made by Cohen (1982, pers. commun.) and Gosselink and Hatton (1984). When observing bulk density versus depth variations for the top 80 cm, a 9.5 times increase in bulk density values appears (Fig. 37, left diagram). But, when plotting bulk density against total depth, a scatter plot appears (Fig. 37, right diagram). Similar relationships were shown by DeLaune et al. (1978) and Gosselink and Hatton (1984) indicating that results from these analyses were reliable despite an error in the procedure (see Methods section).

Moisture / organic matter relationships

Relations between values of moisture and organic matter for different depths can also help understand compaction rates: if, for the same amount of organic matter, samples contain less moisture at greater depth than at shallower depth, compaction has taken place. Relationships between % moisture and % organic matter appear to be log-linear (Fig. 38). Results for samples taken at depths less than 1 m, 1-3 m, and more than 3 m were observed. For 81.7% organic matter, the average for peat in all areas in the delta plain, samples at more than 3 m depth contain 0.28 times less moisture than those at less than 1 m depth in Barataria Basin. The deepest organic-rich sediments (organic-rich phase A) in the bottom of cores BB 31 and BB 9 along cross section B-B' (Fig. 28 and Appendix) have a moisture/organic matter relationship that indicates more compaction for those beds than for surficial beds. Their points are indicated separately on Fig. 38. Burying by a clay lens 50 cm thick (cross section A-A', Fig. 20) caused these organic-rich marsh sediments to be somewhat more compacted than the best-fit log/linear correlation for samples taken at more than 3 m depth predicted.

The ^{137}Cs data, bulk density and moisture/organic matter relationships represent independent variables. All data show that most compaction takes place in the upper 70-80 cm and is negligible below that for sediments of up to 3000 years old. This conclusion agrees well with that of Coleman and Smith (1964) who, on different grounds, argued that differential compaction of organic-rich horizons is minimal.

Accumulation and submergence rates.

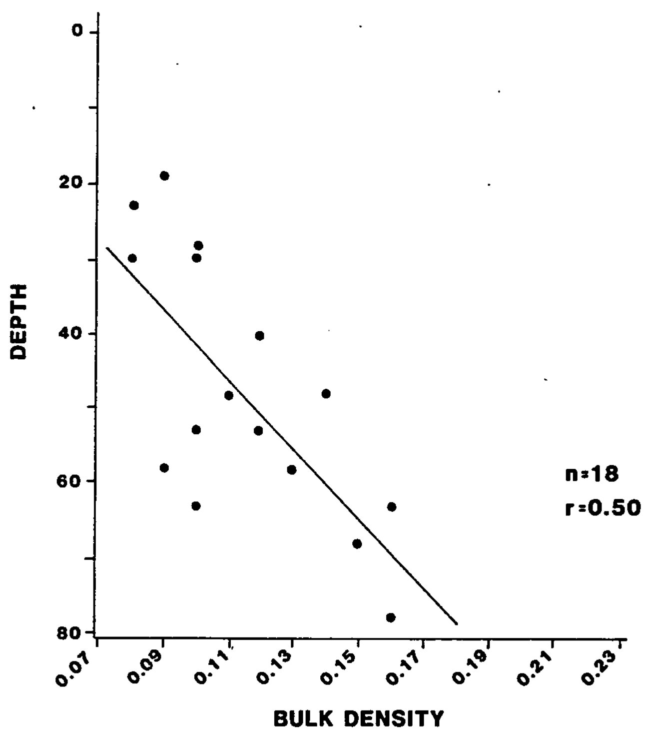
Vertical peat accumulation rates can be calculated by plotting ^{14}C dates of in-situ organic beds against their depth. Assuming that peats accumulated at the surface, i.e., at mean sea level, age/depth relations can yield information on submergence (Coleman and Smith, 1964). In this study, mostly peats from phase B were sampled. Because of uncertainties about surface compaction, only phase B dates were used for calculating accumulation and submergence rates (Fig. 39). The assumption is that compaction in peats of this phase is minimal, as was explained in the previous paragraph. Submergence takes place if sea level rise, subsidence and compaction exceed vertical accretion.

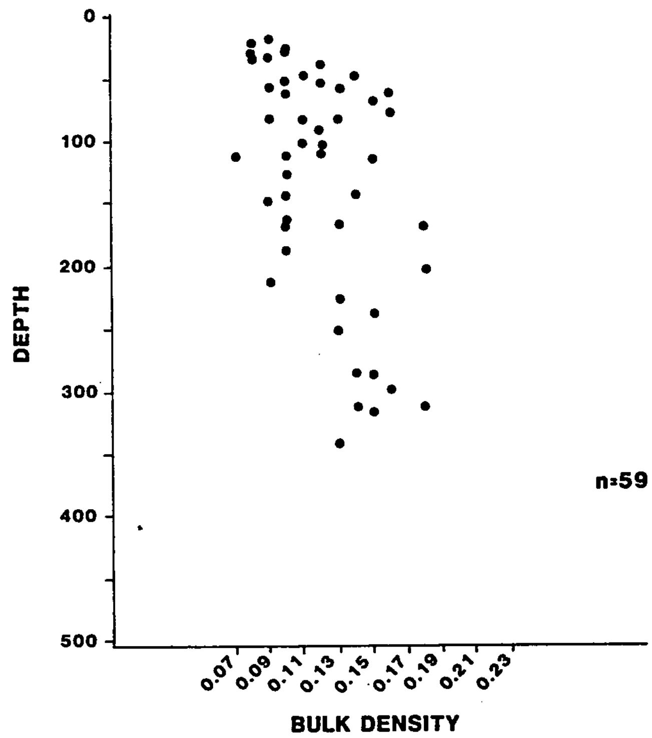
A plot of ^{14}C dates against depth for in-situ peat of phase B in Barataria Basin is shown in Figure 39. Peat samples were all younger than 3000 yBP, so that it can be assumed that eustatic sea level did not change (Coleman and Smith, 1964). The slopes of the linear regression lines are small. Peats in upper Barataria Basin along cross section J-J' (Fig. 15), area 1), accumulated at rates of 0.09 cm/yr, and peats of lower Barataria Basin (area 1) at rates of 0.12 cm/yr. The small accumulation rate for area 2 (H-H', 0.03 cm/yr) was another argument for interpreting the origin of the peat of phase B along H-H' as a flotant.

Submergence rates for areas 1, 2 and 3 average lower than those achieved when plotting ^{14}C dates against depth for Frazier's (1967) samples. Using that method, regional submergencerates for lower Barataria basin average around 0.3 cm/yr. This higher rate incorporates localized consolidation in the top 80 cm, a factor excluded from the Barataria samples, because only phase B peats were used. These data indicate that regional submergence rates were uneven through time and probably higher during progradational stages when sediment loading was higher, and the Lake Borgne fault zone developed.

Figure 37 Relationships between bulk density and depth. At left: relationship between bulk density (g/cm^3) and depth (cm) for the top 80 cm of section. Regression line: $y = -437.27x + 1.72$ with $r = 0.50$. At right: relationship between bulk density (g/cm^3) and depth (cm) for the total section. Mean bulk density for samples taken at depths less than 1 m is 0.11 g/cm^3, for samples taken from 1-3 m is 0.13 g/cm^3, and for samples at depth more than 3 m is 0.15 g/cm^3.

RELATIONSHIPS BETWEEN BULK DENSITY AND DEPTH





LOUISIANA GEOLOGICAL SURVEY

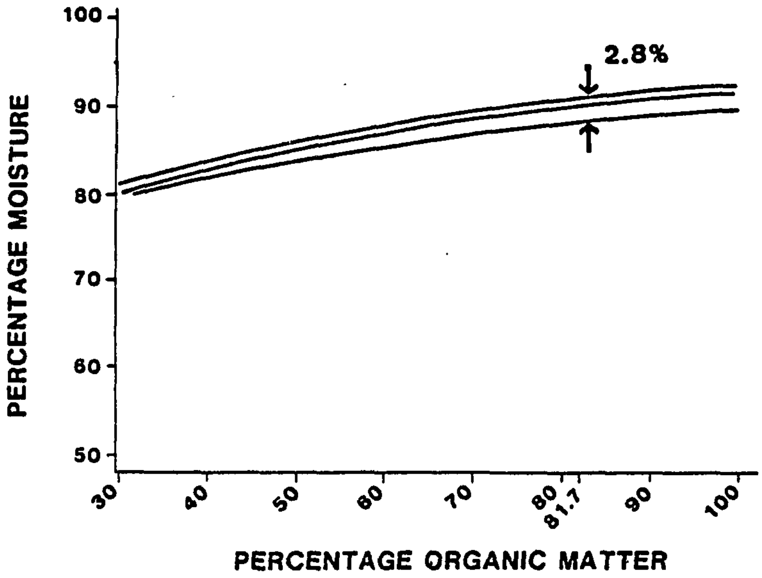
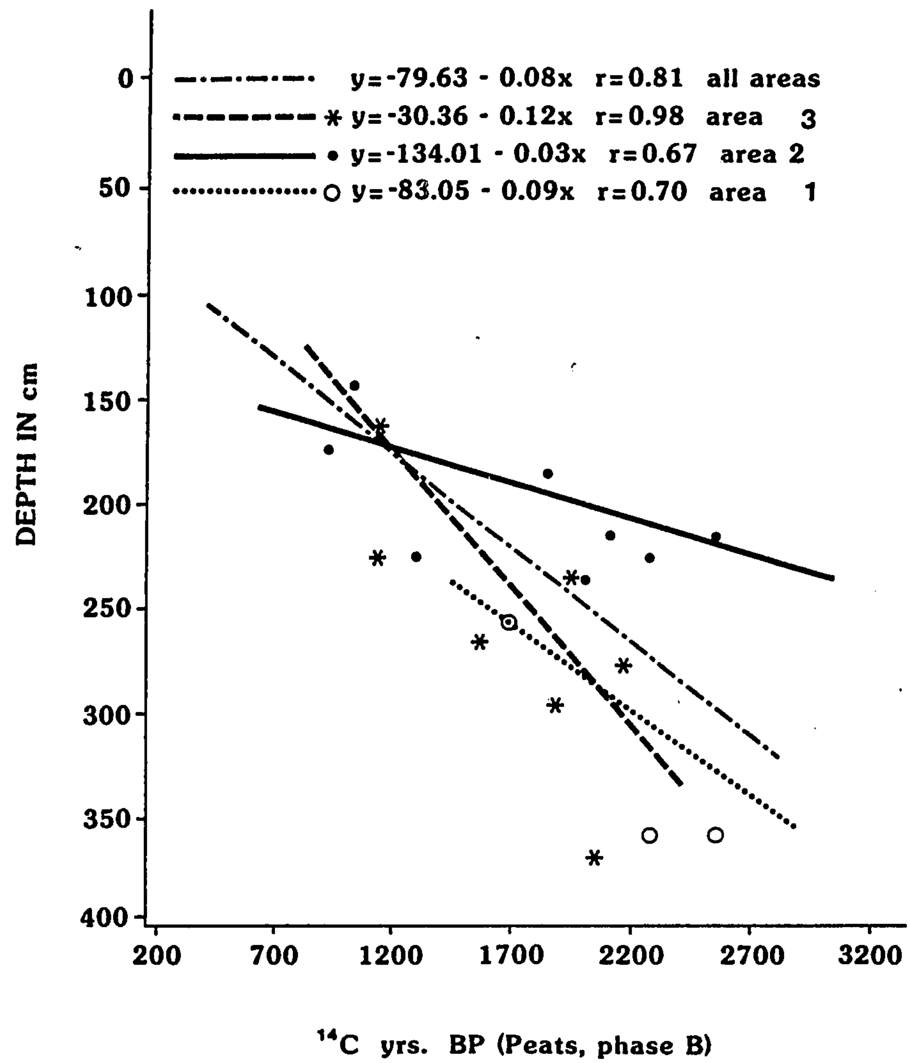


Figure 38 Log-linear relationships between percentage organic matter and percentage moisture. Number of samples = 153. The upper regression line is for samples taken at depths less than 1 m: $y = 9.67 \ln x + 47.97$, with $r^2 = 0.42$. The middle regression line is for samples taken at depths 1 - 3 m: $y = 10.32 \ln x + 44.24$, with $r^2 = 0.64$. The lower regression line is for samples taken at depths greater than 3 m: $y = 8.47 \ln x + 50.49$, with $r^2 = 0.50$. For 81.3% organic matter, the average peat quality in South Louisiana, compaction is 2.8% in the top 4 m of section.

Figure 39 Linear regressions for ^{14}C dates against depth for samples from peat phase B in Barataria Basin. Area 1: Lac des Allemands to Des Allemands (cross section J-J'); Area 2: Des Allemands to Lake Salvador (cross section H-H'); Area 3: Lake Salvador to Little Lake. Thick line represents compiled regression for all areas. Dot in circle on regression for area 1 represents two data points.


y=-79.63 - 0.08x r=0.81 all areas
* y=-30.36 - 0.12x r=0.98 area 3
• y=-134.01 - 0.03x r=0.67 area 2
○ y=-83.05 - 0.09x r=0.70 area 1
DEPTH IN cm
0
50
100
150
200
250
300
350
400
200
700
1200
1700
2200
2700
3200
^{14}C yrs. BP (Peats, phase B)

Effects of submergence and compaction on peat accumulation

More peat occurs in the upper than in the lower basin (Table I, II). Regional subsidence rates appear to play a minor role in this phenomenon, since they balance subsurface vertical accretion rates, as shown above. The deltaic package is much thicker in the lower basin than in the upper basin (McFarlan, 1961; Kolb and Van Lopik, 1958), so that submergence and subsidence during loading downdip of the Lake Borgne fault zone was possibly greater in the lower basin, creating a deeper depression (cf. H-H' and A-A'). The deeper downdip part of Barataria Basin was more prone to flooding and marine influence than the shallower updip part, causing more organic-rich material to accumulate in the lower basin and more peat in the upper basin.

Peat-to-coal compaction.

When peat-to-coal compaction is discussed in the literature, thickness (and thus volume) changes are implied. Ryer and Langer (1980) list ratios of peat-to-coal-transformation as reported throughout the literature by numerous researchers. Rates vary from 2.5:1 to 50:1 with a mean of 7.5:1. Ryer and Langer (1980) accept a 11:1 ratio for a fluvial coal that originated near a meandering stream. Peat in the Mississippi Delta has an average moisture content of 90%. Lignite contains about 40% moisture and anthracite about 2.3% (Pampe, 1981). Thus, due to the loss of water, considerable compaction has to take place during coalification, and from these moisture contents, a ratio of 10:1 is reasonable. However, it is unclear in which stage of coalification the compaction occurs.

The thickest peat beds occur in cores BB 71, BB 40, and BB 94 (Appendix A, p.234, 203 and 257), but none of these are thicker than about 1.25 m. If a peat-to-coal transformation rate of 10:1 is about correct, Modern Mississippi Delta peats would produce coal seams with maximum thicknesses of 10-15 cm.

DISCUSSION.

PARAMETERS OF PEAT FORMATION IN THE MISSISSIPPI DELTA

The previous sections have described the sedimentology, stratigraphy, and physical properties of selected peat-forming environments in the Modern Mississippi Delta Plain. Results of the investigation indicate that the following parameters and processes control the formation of peat beds and relate to peat formation in a deltaic setting:

1) *composition of botanical parent material*,
2) intermittent subaerial decomposition processes (degree of exposure to oxidation processes), or alternating redox environments,
3) the balance between localized consolidation, regional subsidence and vertical marsh accretion rates,
4) influx of coarse- and of very fine-grained detrital clastic sediments on different time scales,
5) degree of exposure to salt water.

The botanical origin of these peats, namely as fresh water forested swamps and herbaceous, probably largely floating marshes is most likely an important factor in determining their overall high mean ash content. It is unknown how much inorganic material these vegetative communities contribute. Because the communities are unable to create a perched water table and thus intermittently expose the marsh surface to subaerial decomposition, the organic matter content of the resulting peat decreases at times, probably over large surface areas. This process is not as important in floating marshes, which are considered the most likely environments for generating high-quality peats. Present-day freshwater swamps produce only organic-poor beds.

Localized consolidation and submergence are important in this setting, and peat can only continue to form when submergence rates balance with vertical marsh accretion. If vertical accretion exceeds the combined effects of subsidence, temporary subaerial oxidation and decomposition become dominant, decreasing preservation of subsurface organic matter. When submergence exceeds the combined effects of accretionary processes, marshes "drown". Since peat accumulation rates may average 0.08 cm/yr, combined rates of that range will tolerate for peat accumulation.

Coarse-grained detrital clastic sediment influx will "choke" the marsh and temporarily decrease organic production. Detrital clastic influx may occur on different time-scales associated with:

1) yearly overbank flooding,
2) delta lobe switching.

The influx of more fine-grained material (resulting in organic-poor beds) is probably beneficial for peat accumulation. Such sediment influx may provide plants with nutrients, and a "platform" for growth (see Horne et al., 1978). On the other hand, peats may form topographic lows that are prone to flooding. Flotants do not require detrital clastic influx for the purpose of building a platform, but a certain amount of clastics may provide necessary nutrients.

Marine inundation occurs after delta lobe abandonment. Active sedimentation is then diverted from the area and submergence become dominant. Saline marshes never contain more than 35% organic matter. Thus, marine conditions effectively terminate peat accumulation; the best example of this process can be found in the Avery Island area, where organic-poor horizons of saline marsh origin transgressively overlie fresh water peats. In the lower delta plain and back-barrier areas, peats do not occur due to the influence of saline waters.

CONCLUSIONS.

1. A typical sequence of large-scale interdistributary basin fill consists of detrital clastic lithologic, capped by organic material, with numerous intercalations of mud-sized material. This sequence is about 6 m thick in Barataria Basin.
2. Peats in the Mississippi Delta Plain average 81.27% organic matter with a range of 74.90 - 93.36%, and a standard deviation of 3.80.
3. The fact that peats in the Mississippi Delta are of a eutrophic origin (planar or non-bog) probably contributes to this relatively high ash content.
4. Peats originate in fresh forested swamps and in fresh, often floating marshes. In minor amounts, peats originate in fresh, sedge-type marshes.
5. Differences in mean quality between different study areas are very small, but lower Barataria Basin and Gueydan peats, which are of fresh marsh origin, have a lower mean organic matter content than peats in other areas, which often originated in fresh swamps.
6. Quantities of peats, as determined from core-derived organic matter data, are higher in the upper interdistributary basin than in the lower interdistributary basin.
7. Quantities of peats, as determined from core-derived organic matter data, increase linearly with increasing amounts of organic-poor material, with a correlation

coefficient of 0.75, possibly indicating that detrital clastic influx of very low physical energy is beneficial for peat accumulation.

8. Saline marshes produce only organic-poor horizons in the subsurface. This effect can be contributed to increased aerial exposure and decomposition of plant material, detrital sedimentation due to tidal effects, and bacterial activity in saline environments.
9. Peat and organic-rich horizons are always part of the same strata, and the quantity of peat as determined from core-derived organic matter data increases with decreasing amount of organic-rich material (r=-0.85), indicating that these are ecologically similar environments.
10. Initial dewatering of marsh sediments immediately after accumulation in the upper 70-80 cm accounts for about 30-70% of early compaction, but in later stages, differential compaction is minimal compared to overall subsidence.
11. A lack of sufficient time is an important factor limiting the thickness of deltaic peat beds. These marsh deposits have only accumulated since the beginning of the Holocene and the frequent switching of delta complexes has shortened periods of marsh accumulation even more.
12. Non-ombrogenous vegetation, not being able to create a perched water table, will probably experience increased

degrees of decomposition at times, and this may result in decreased organic matter production, thus explaining alternation of organic-rich and peat beds. This process is less likely to occur in floating marshes, which are thought to be very good candidates for peat deposits. Deltaic areas may contain extensive flotants during periods of rapid sea level rise, suggesting that coals have formed associated with flotants.

13. The parameters that control peat accumulation in the Mississippi Delta are thus: botanical parent material, the balance between subsidence and accumulation rates, clastic detrital influx (with the understanding that subsidence creates a low that can be filled with clastic detrital material), marine inundation (as a result of increased subsidence and lack of detrital influx), and frequency of delta lobe switching.

14. In the context of the total Mississippi Delta system, peat accumulation is contemporaneous with active deposition of terrigenous clastic sediments, but on a more local scale, there is a hiatus between coarse clastic deposition and peat accumulation.

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Appendix: Core Legend and Graphic logs of cores BB 1-95 and cores AI 1-9.

LEGEND

TEXTURE

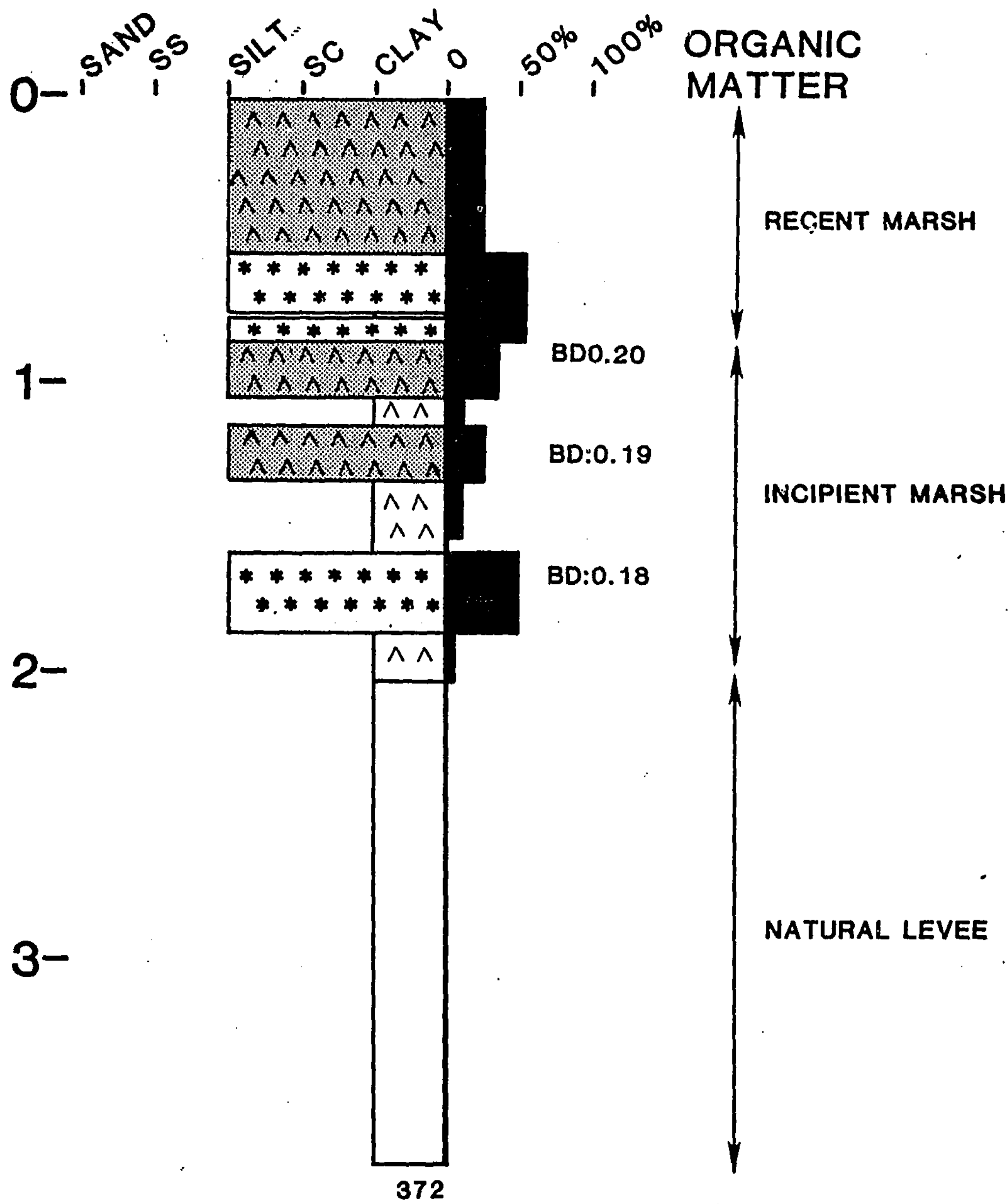
- Peat
- Organic-rich Marsh (35-75% organic matter)
- Organic-poor Marsh (15-35% organic matter)
- Organic-rich Clay (5-15% organic matter)
- Non-organic clay, silts, and sands according to grainsize column
- Alternation of grain size on a lamination scale

STRUCTURE

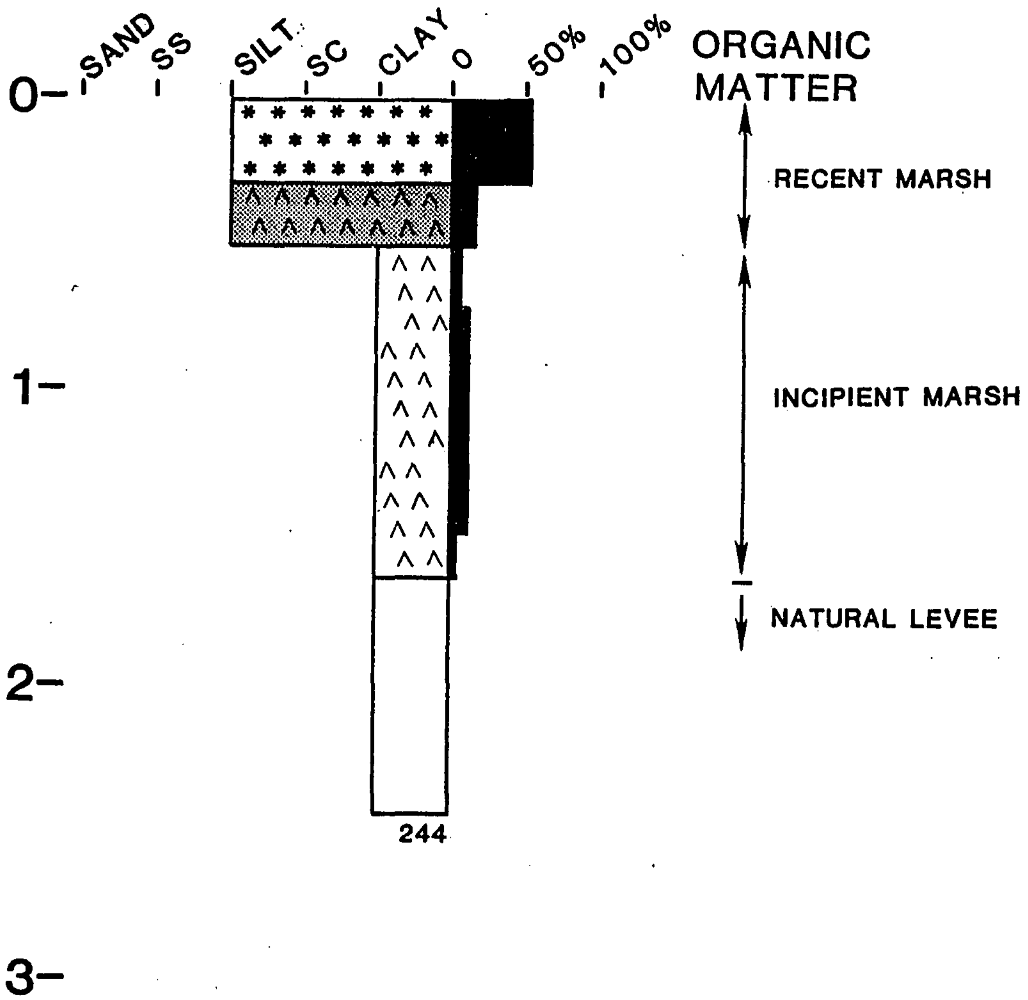
- small scale low-angle cross-stratification
- lenticular bedding
- tabular crossbedding
- parallel lamination
- wavy lamination
- oscillation ripples
- starved ripple
- rip-up clasts
- disturbed bedding
- convolution
- mudcracks
- shallow scour
- thin clay lenses in organic-rich marsh and peat

- wood fragment
- roots
- X charcoal
- lenses of organic remnants
- Rangea cuneata shell hash
- whole shells of Rangea cuneata
- in situ hinged Rangea cuneata
- Crassostrea Virginica
- gastropode
- Sid siderite band
- OX oxidized sediment
- C^{14} radio carbon date
- BD: Bulk Density (g/cm)

VIBRACORE BB1 / 50CM COMPACTION



VIBRACORE BB2 / 45CM COMPACTION



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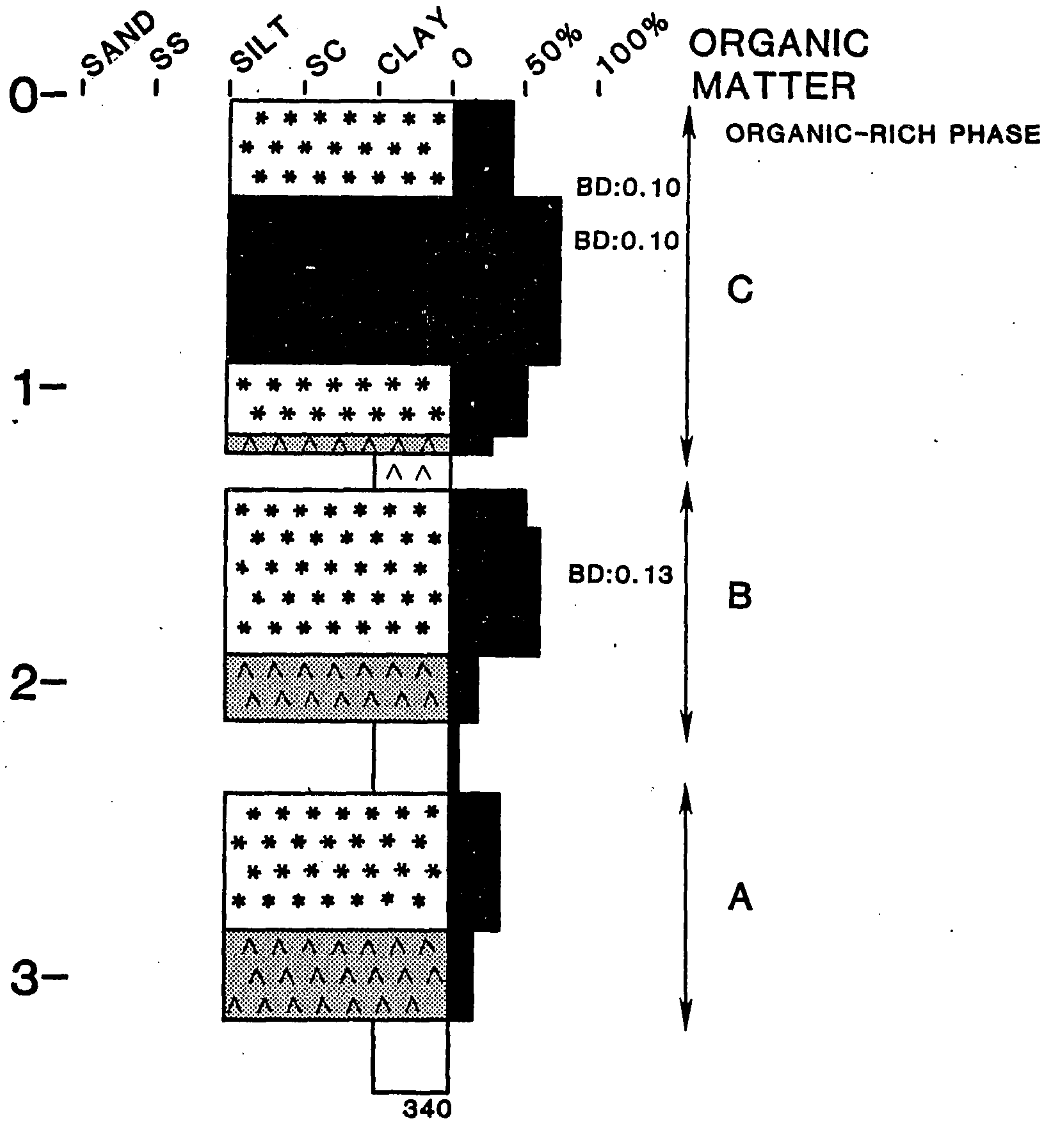
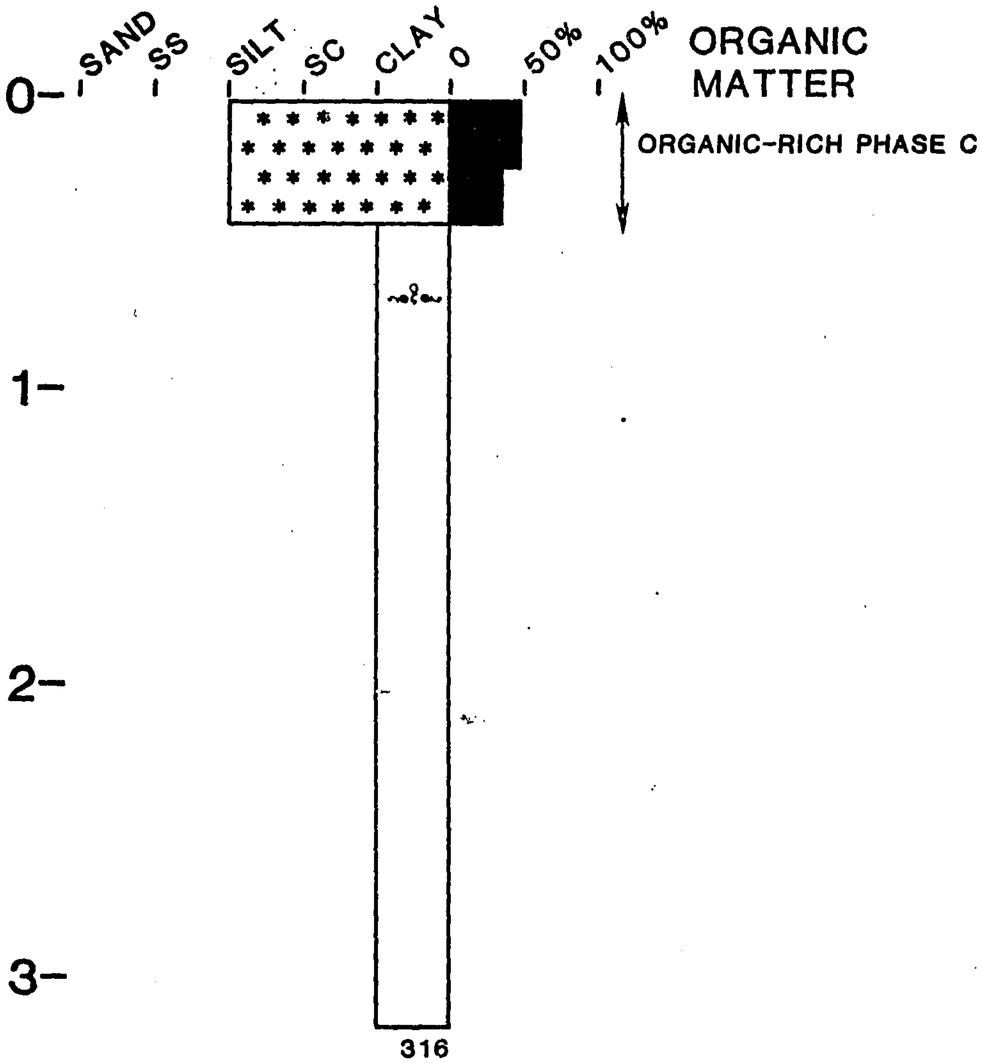


VIBRACORE BB4 / 95CM COMPACTION



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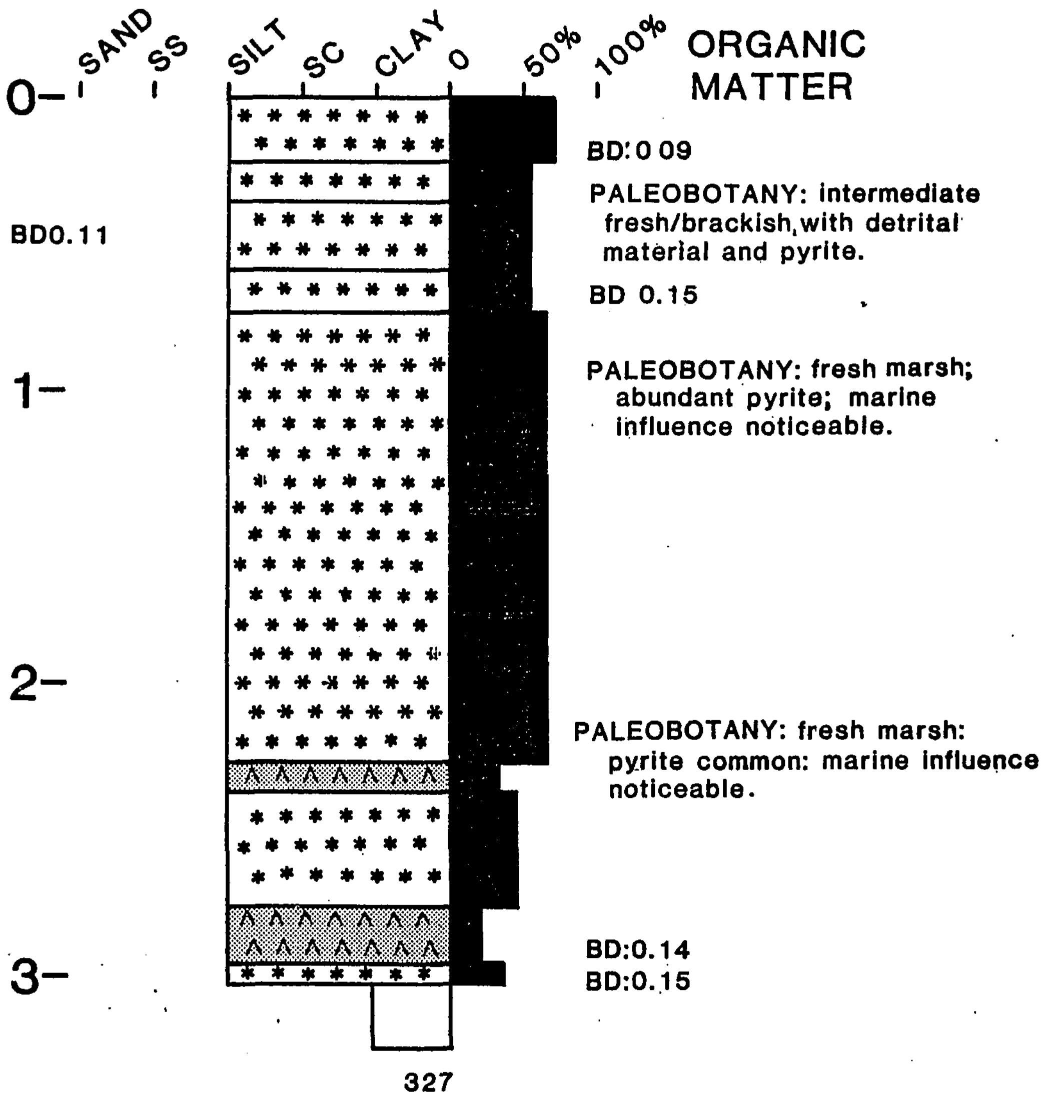

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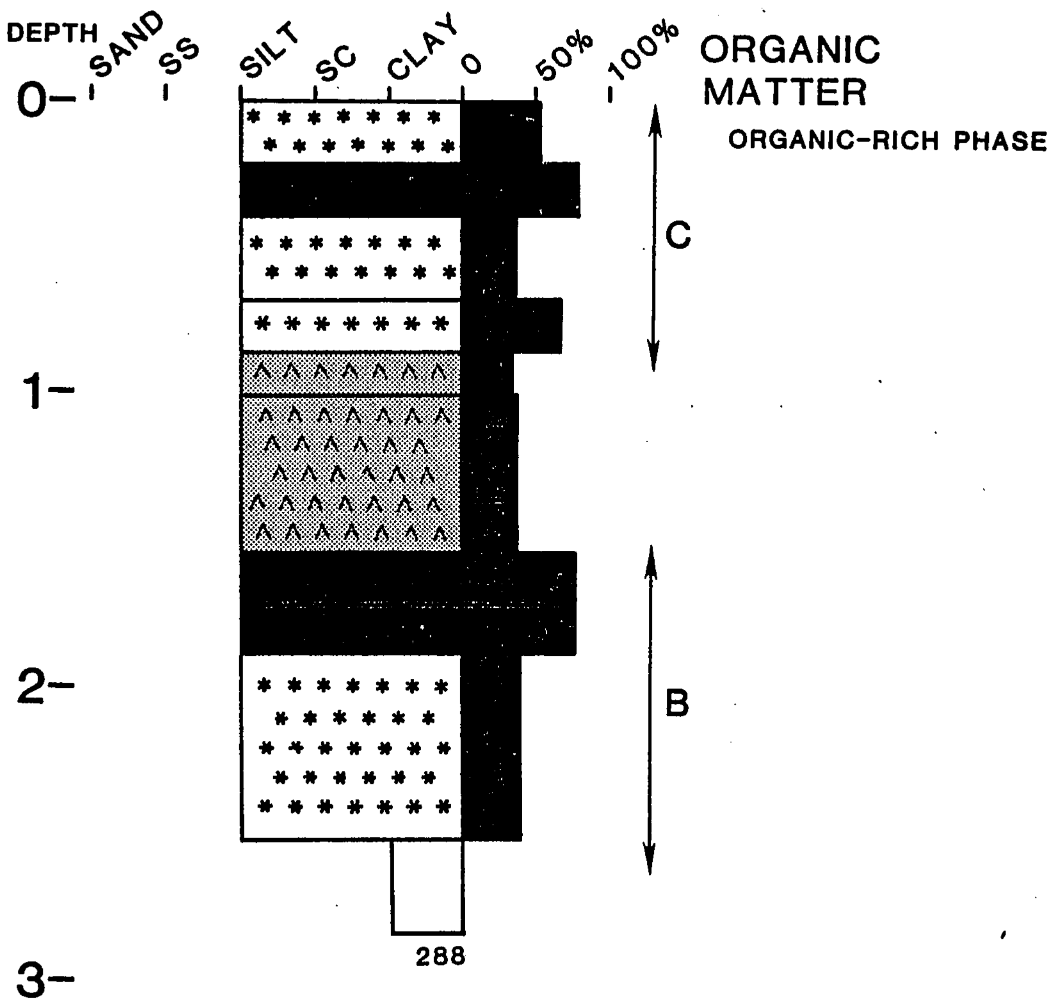

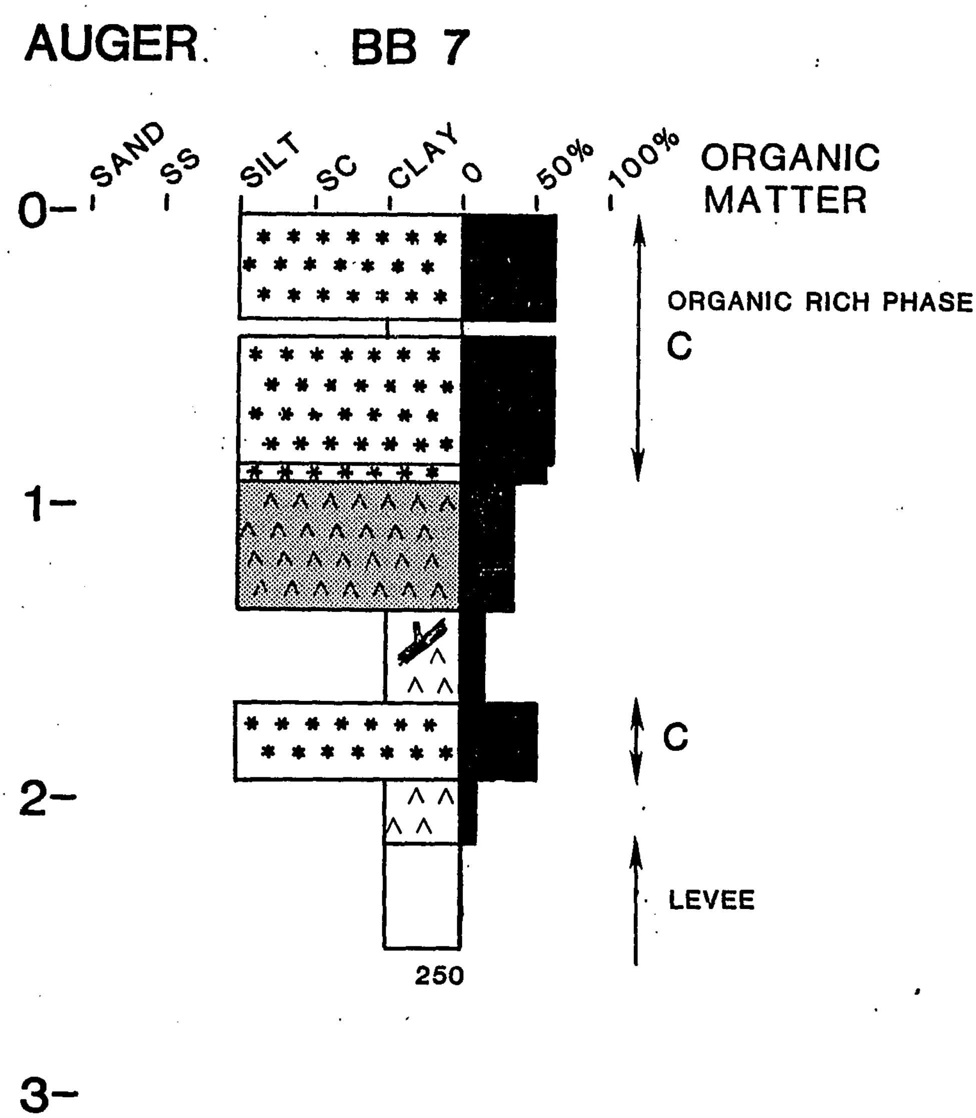
AUGER
BB 7
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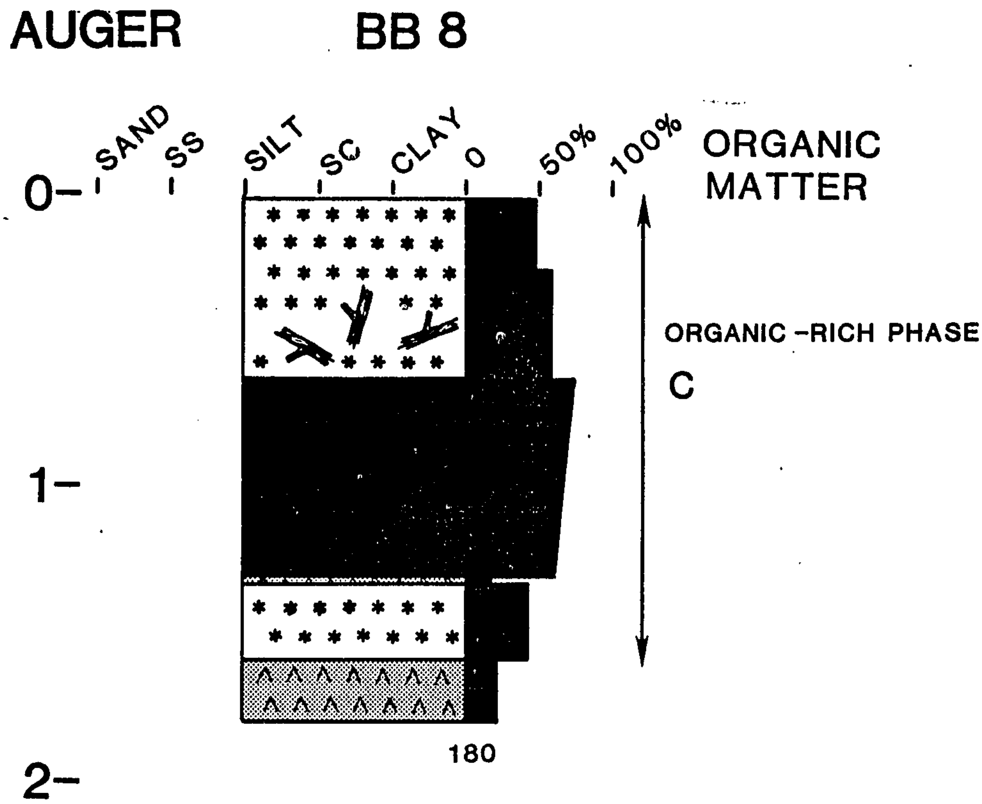
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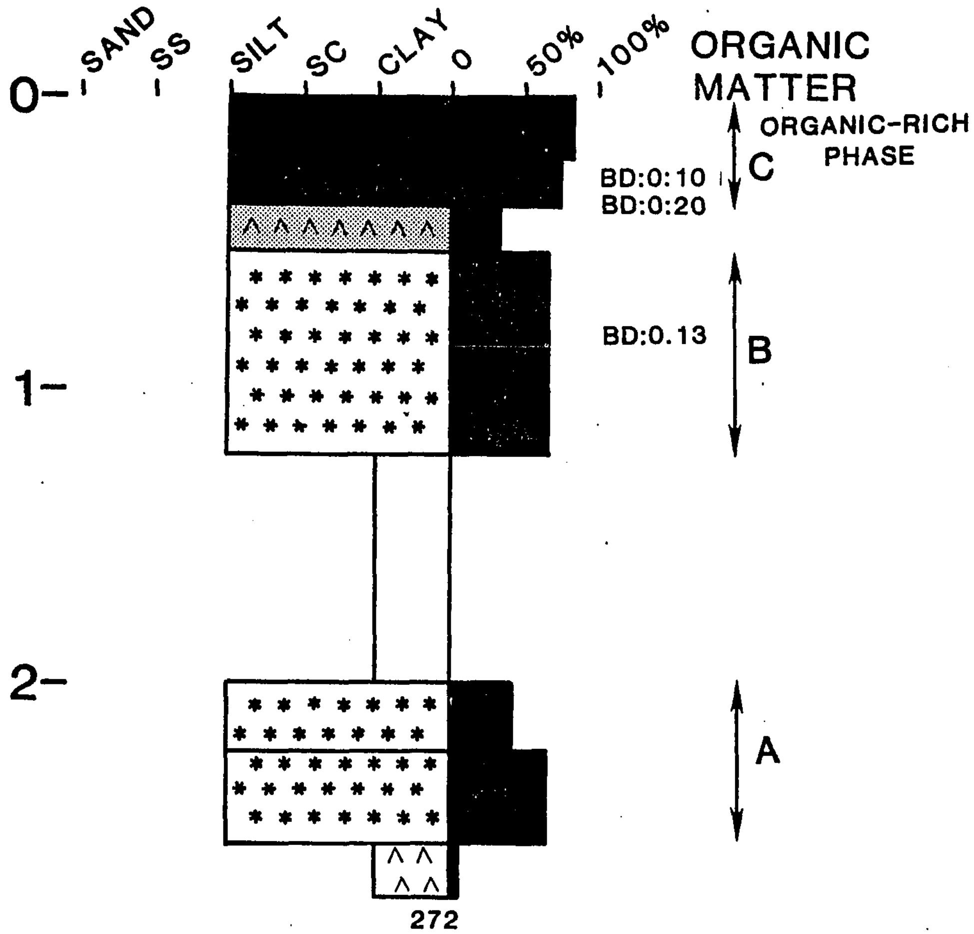
VIBRACORE BB9 / 135CM COMPACTION



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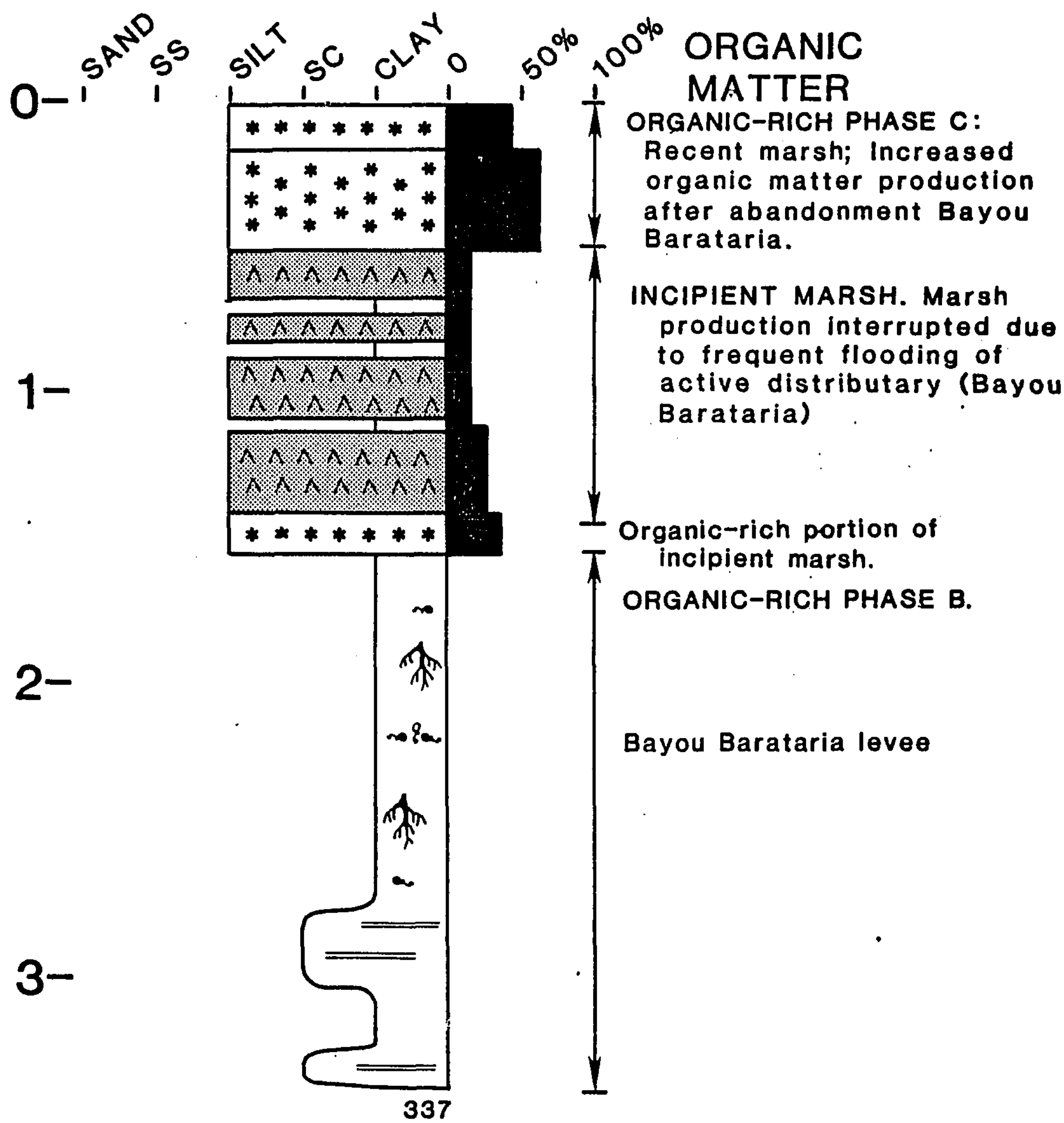

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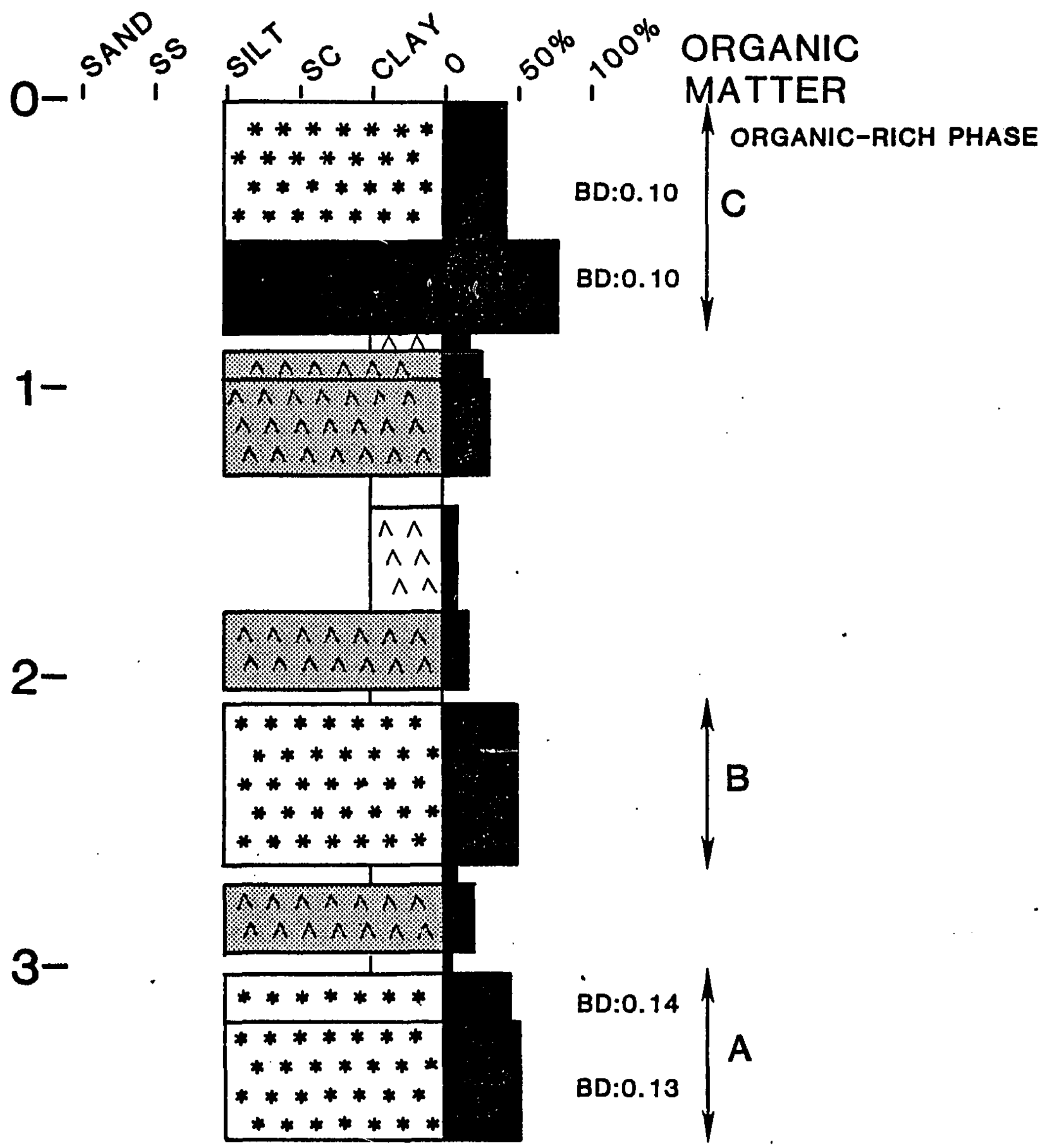

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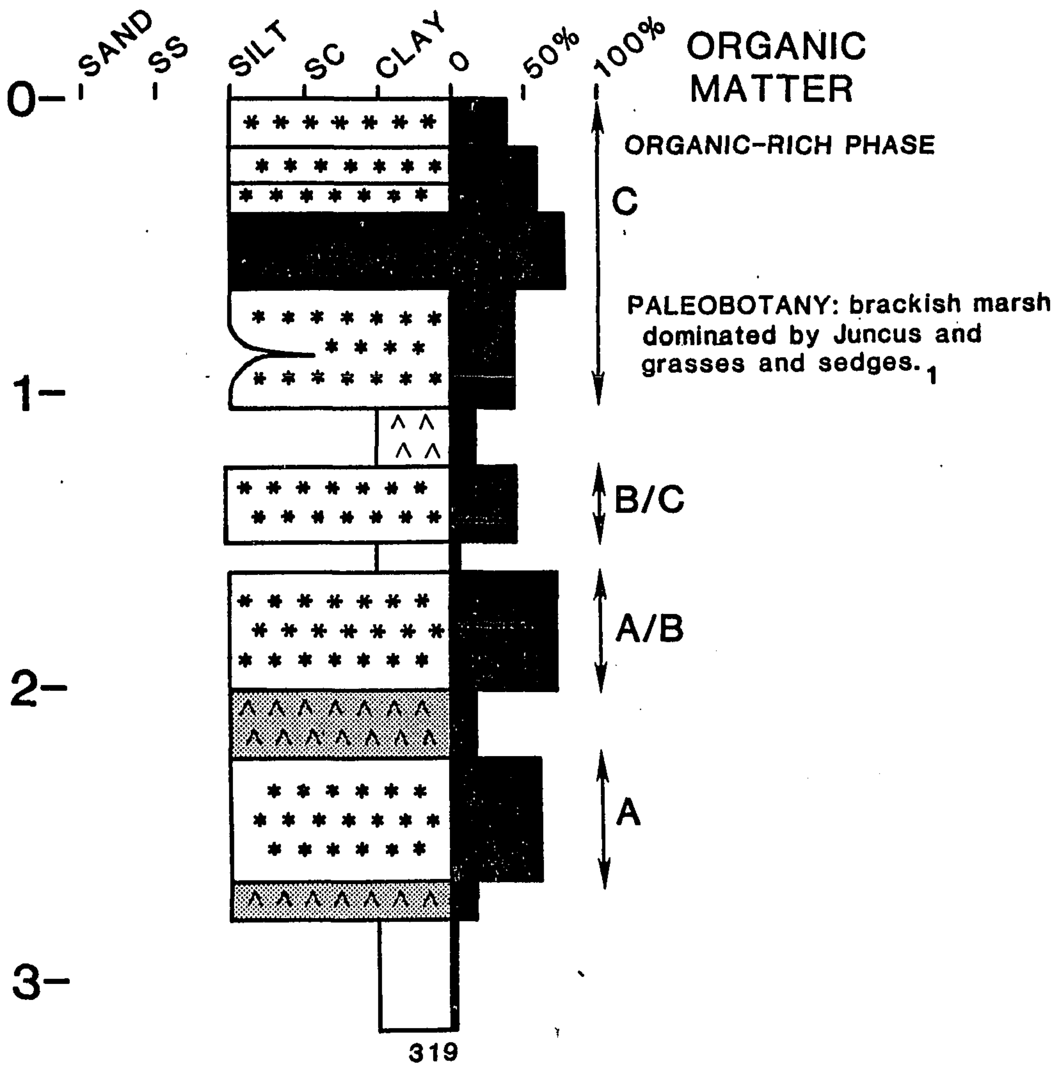

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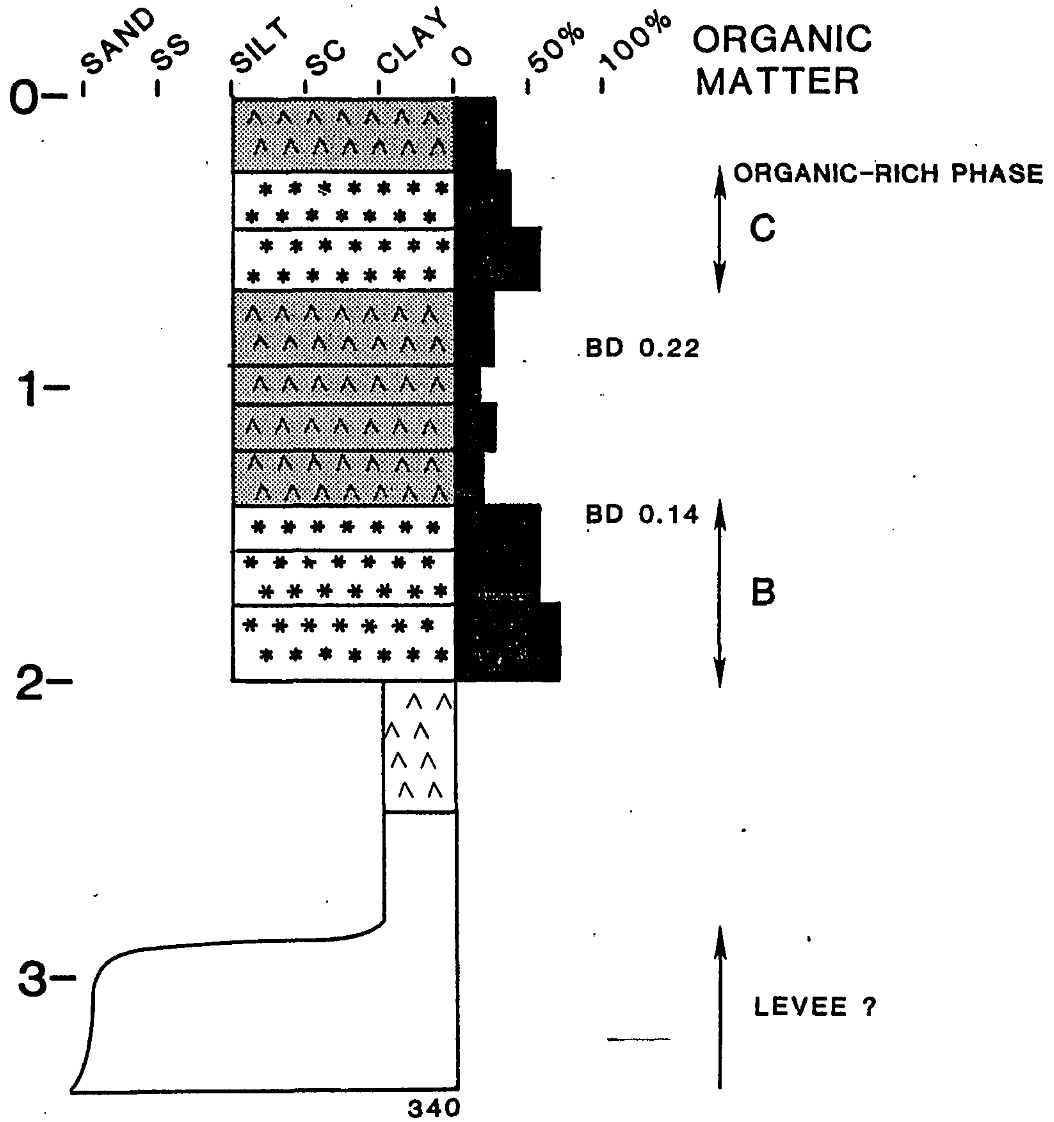

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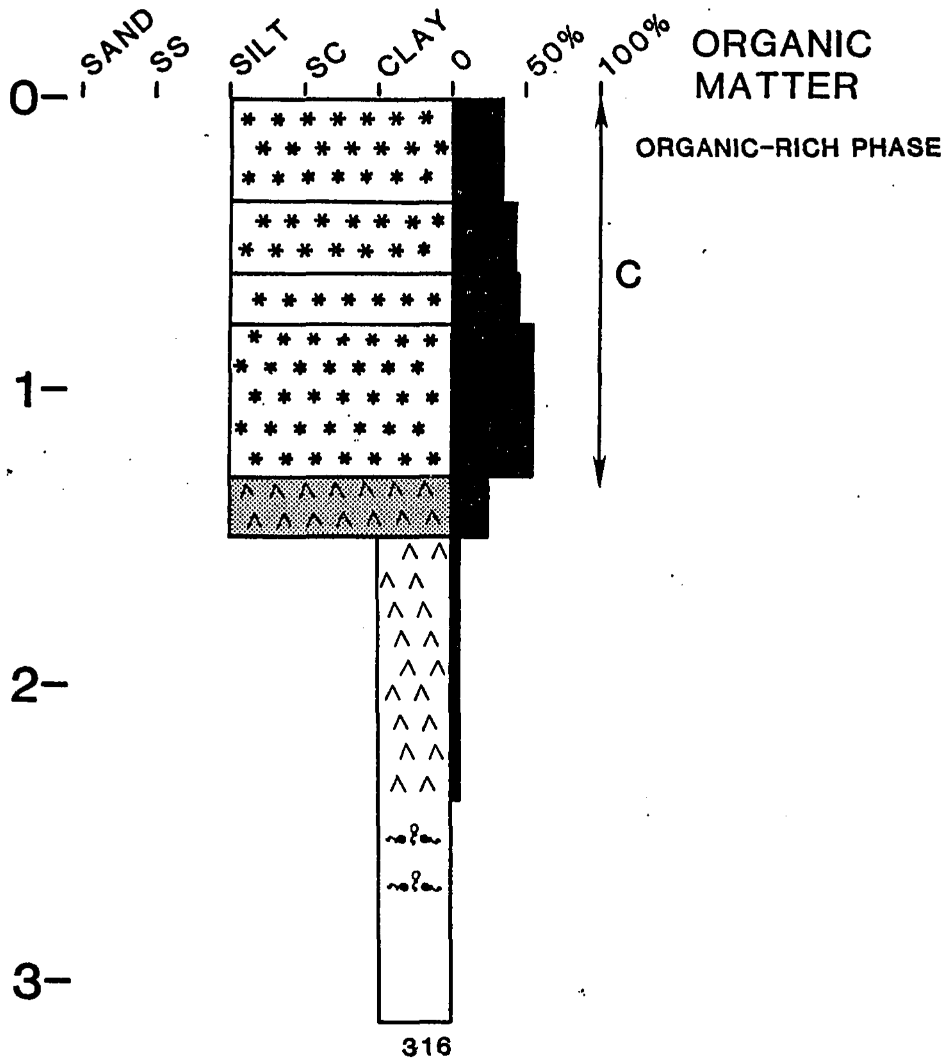
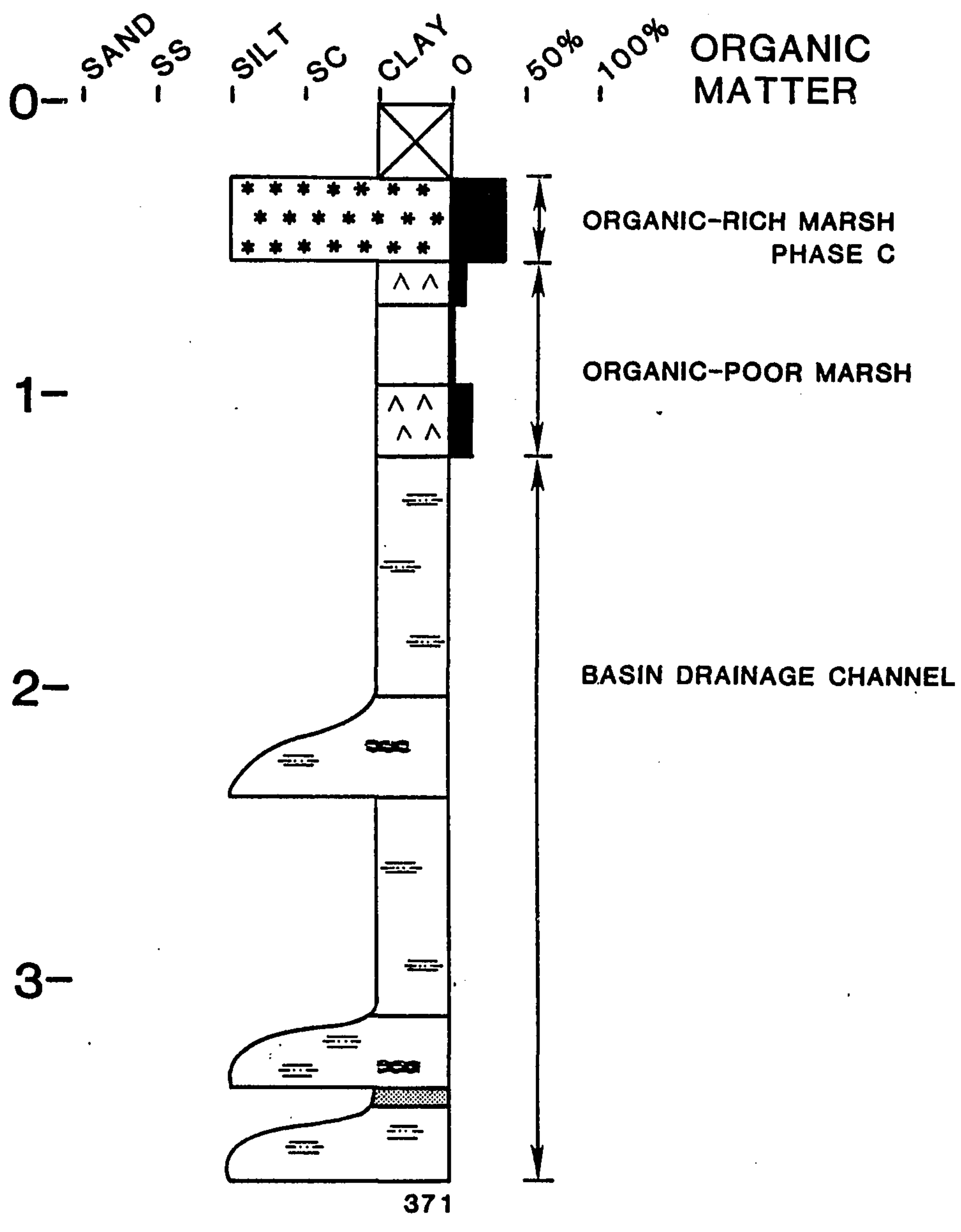
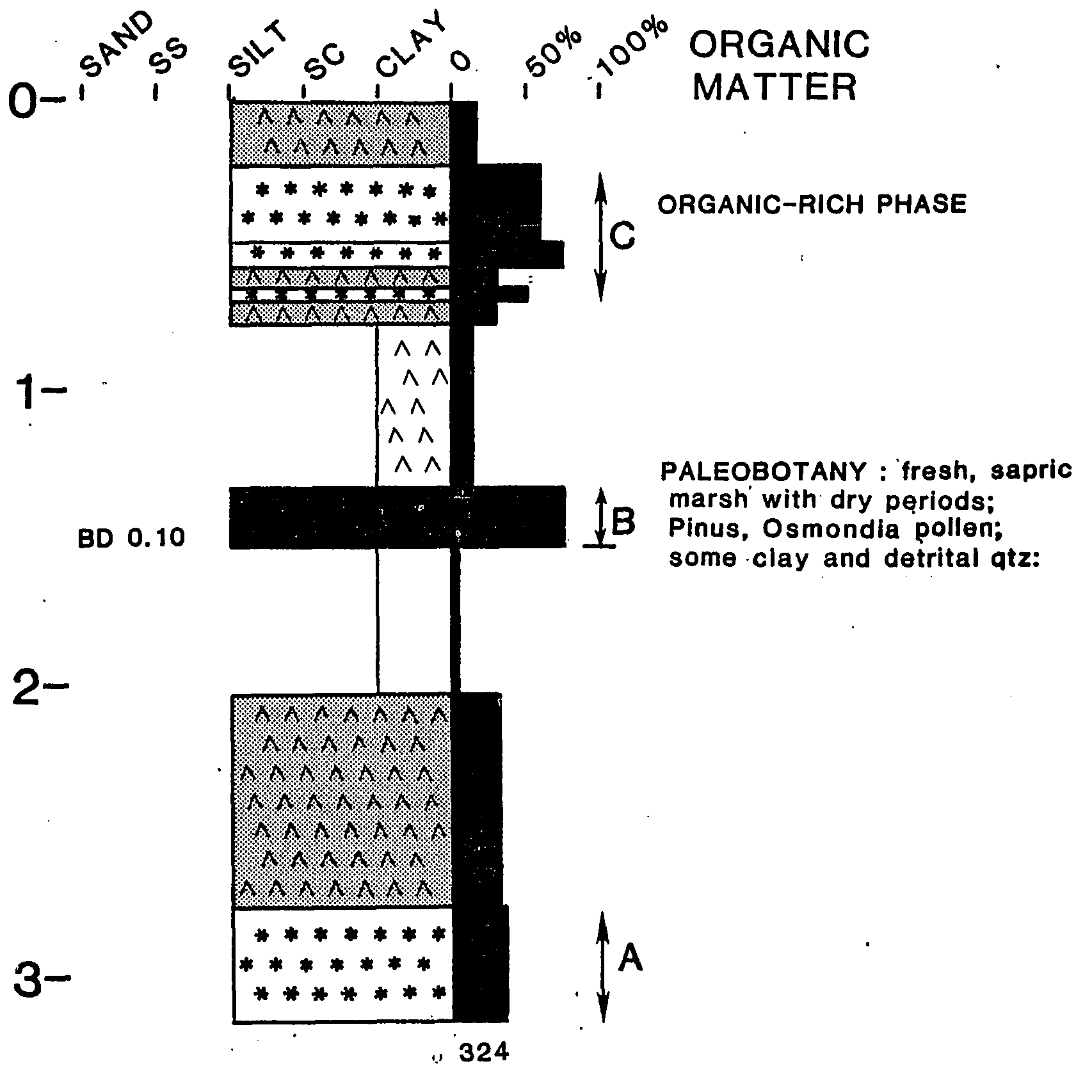


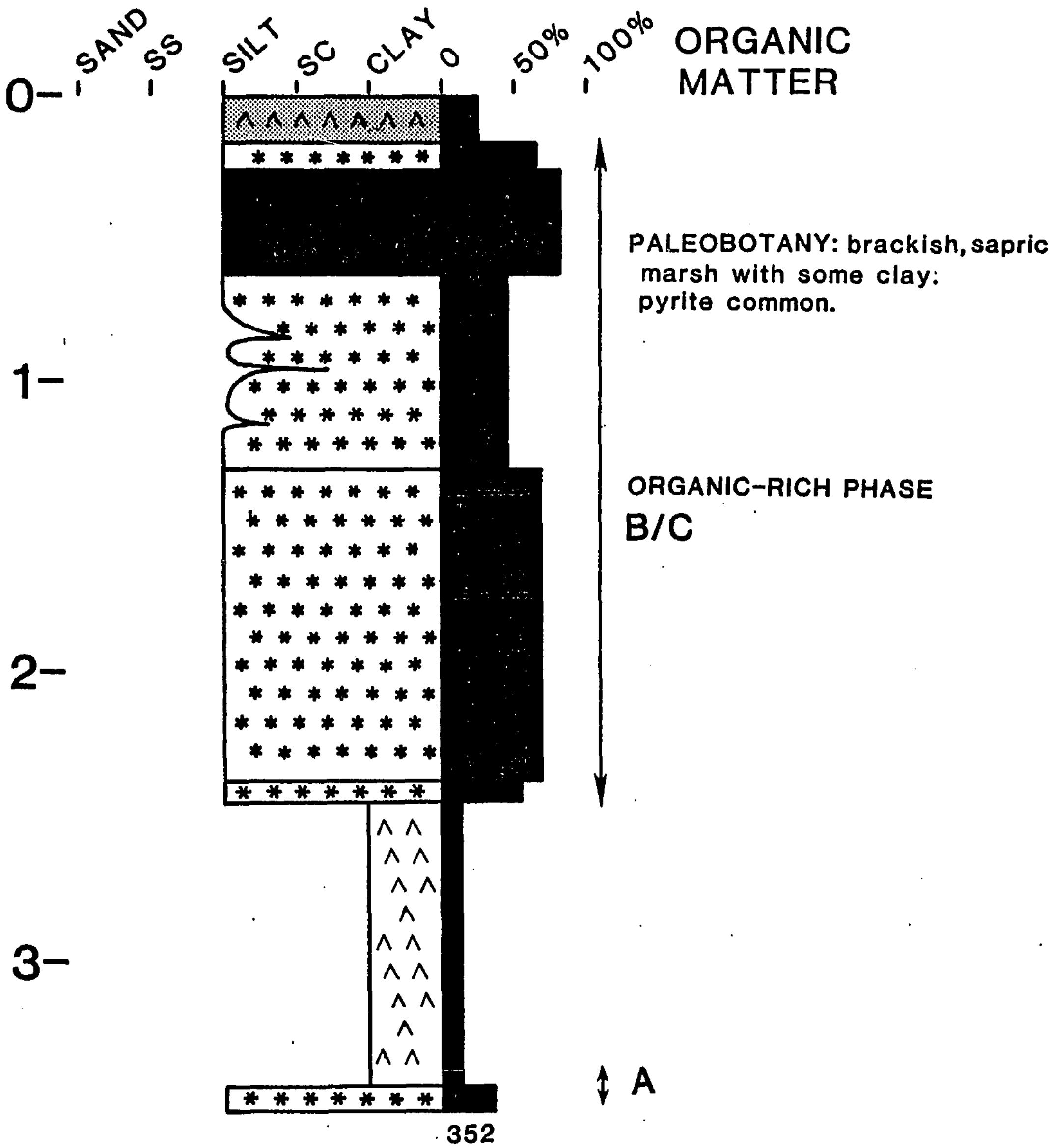
VIBRACORE BB15 / 40CM COMPACTION



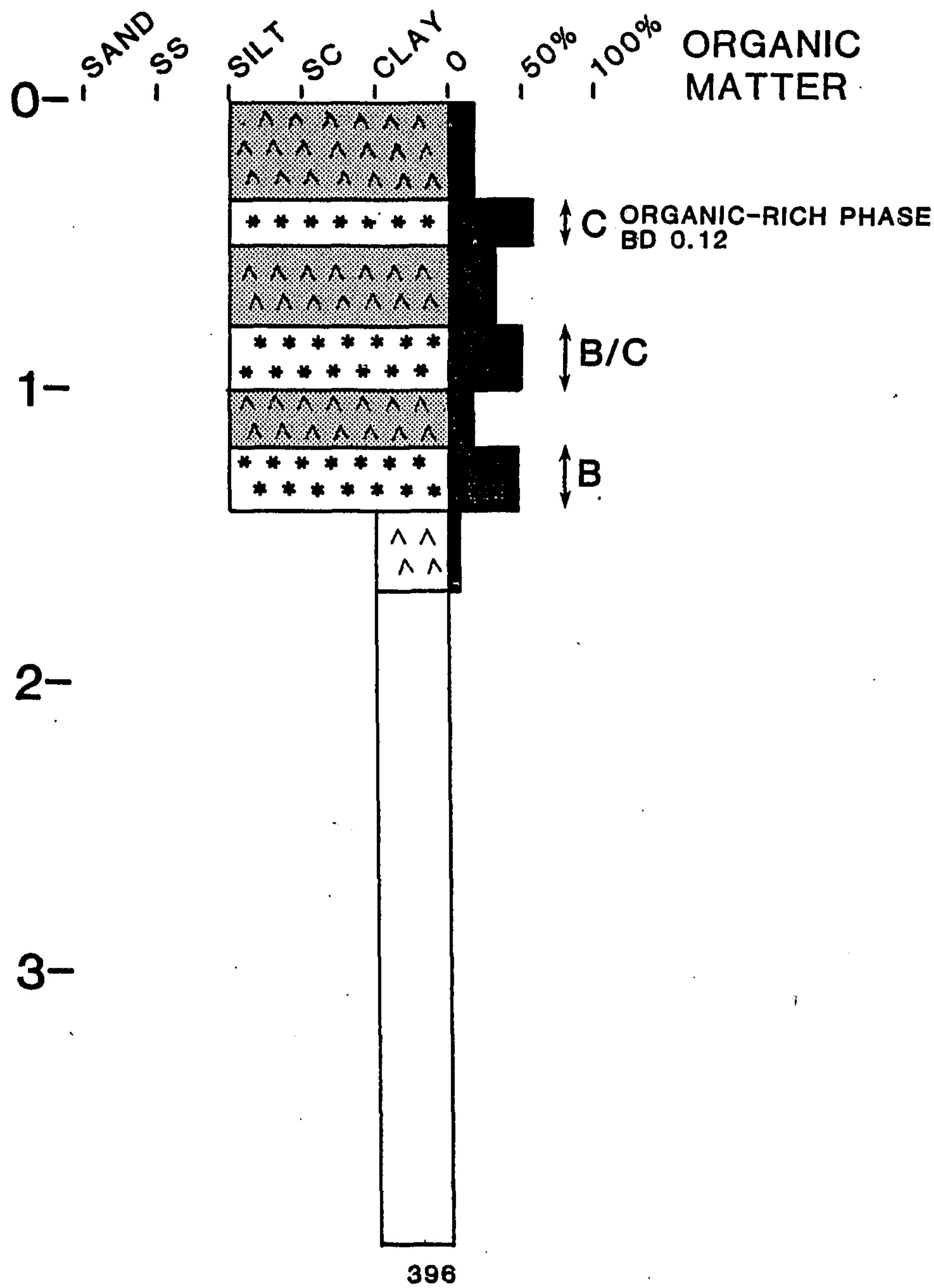
VIBRACORE BB16 / 64CM COMPACTION



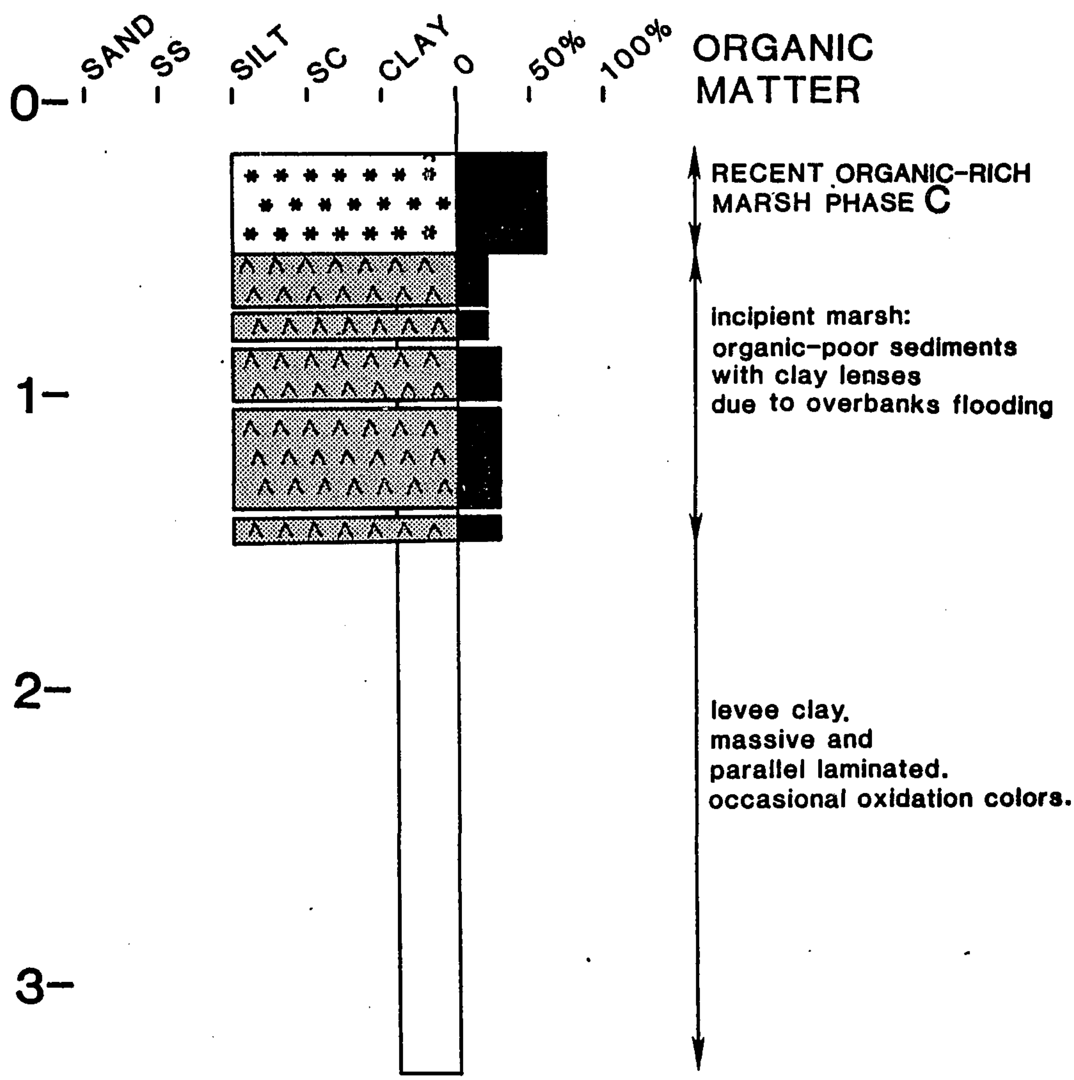
VIBRACORE BB17 / 85CM COMPACTION



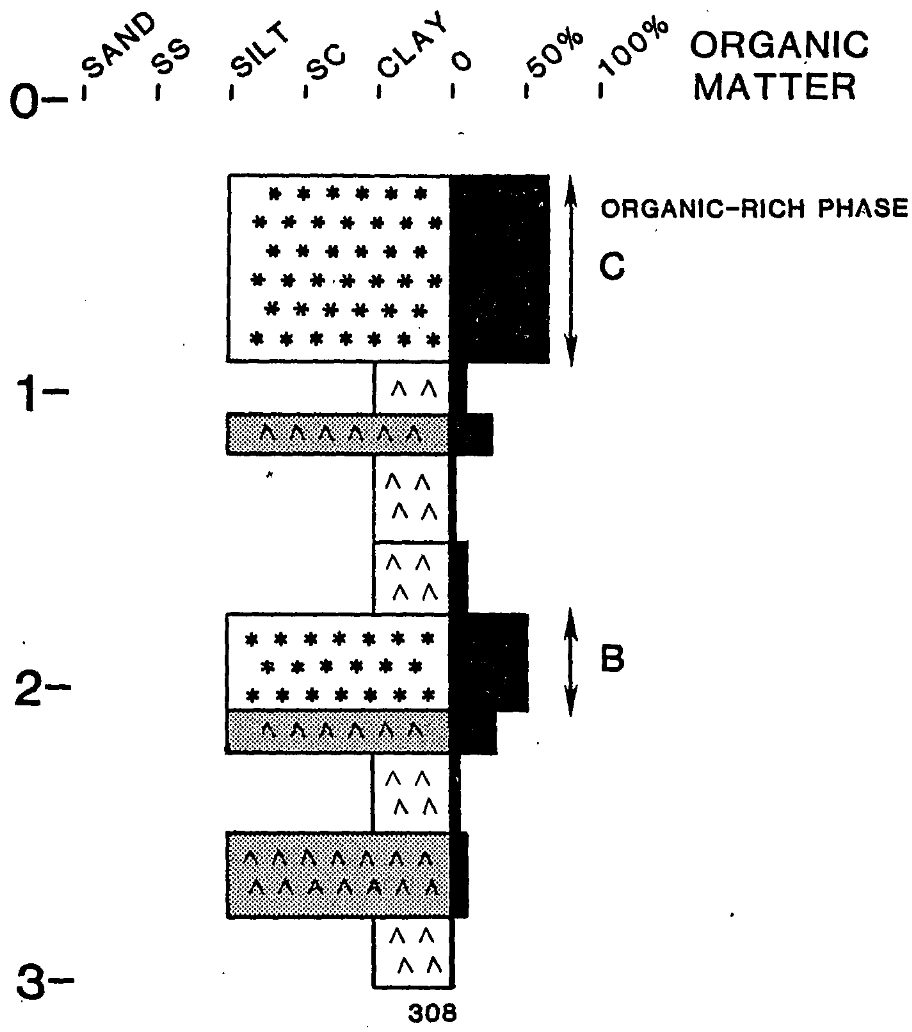
VIBRACORE BB18 / 55 CM COMPACTION



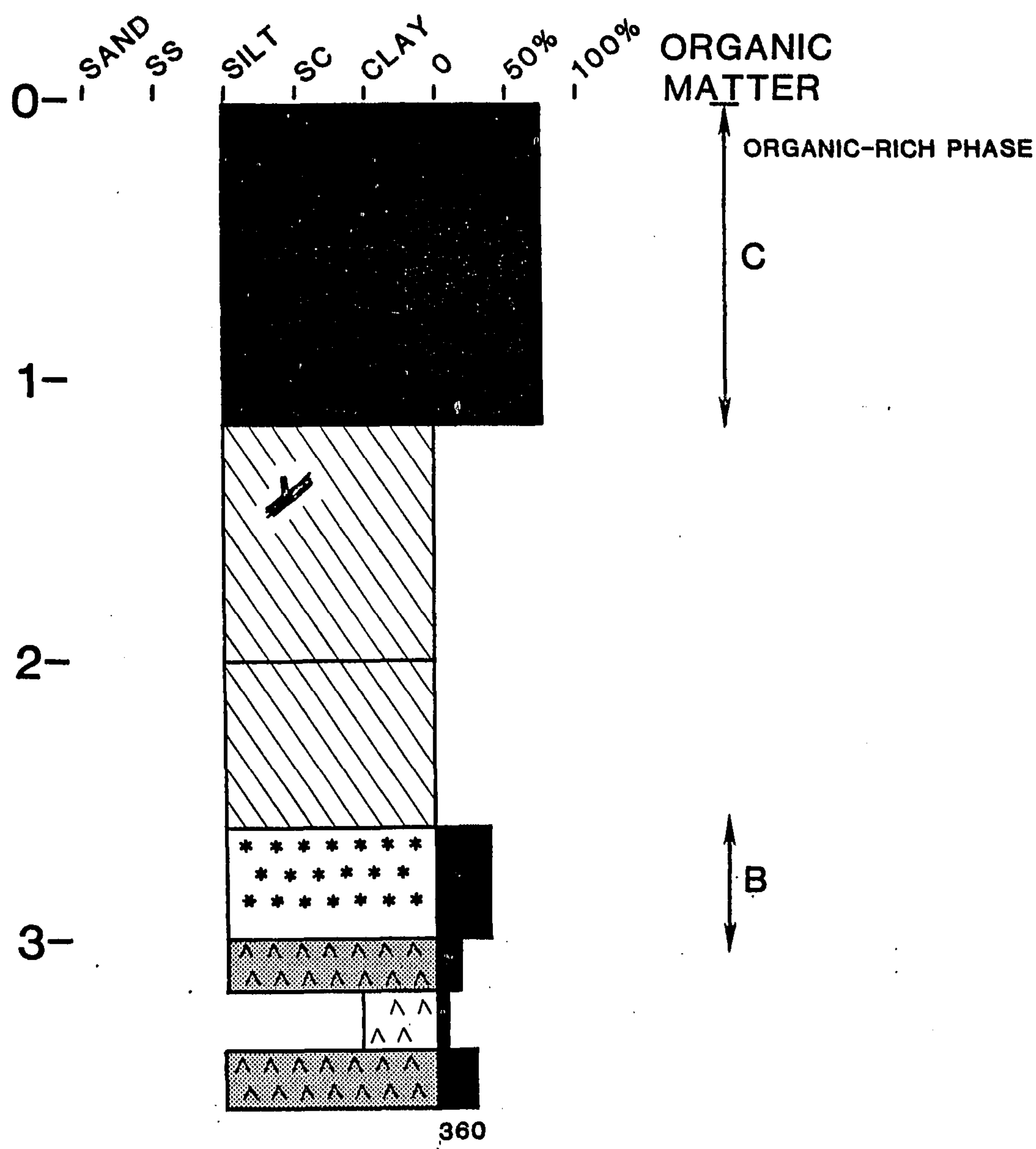
VIBRACORE BB19 / 68 CM COMPACTION



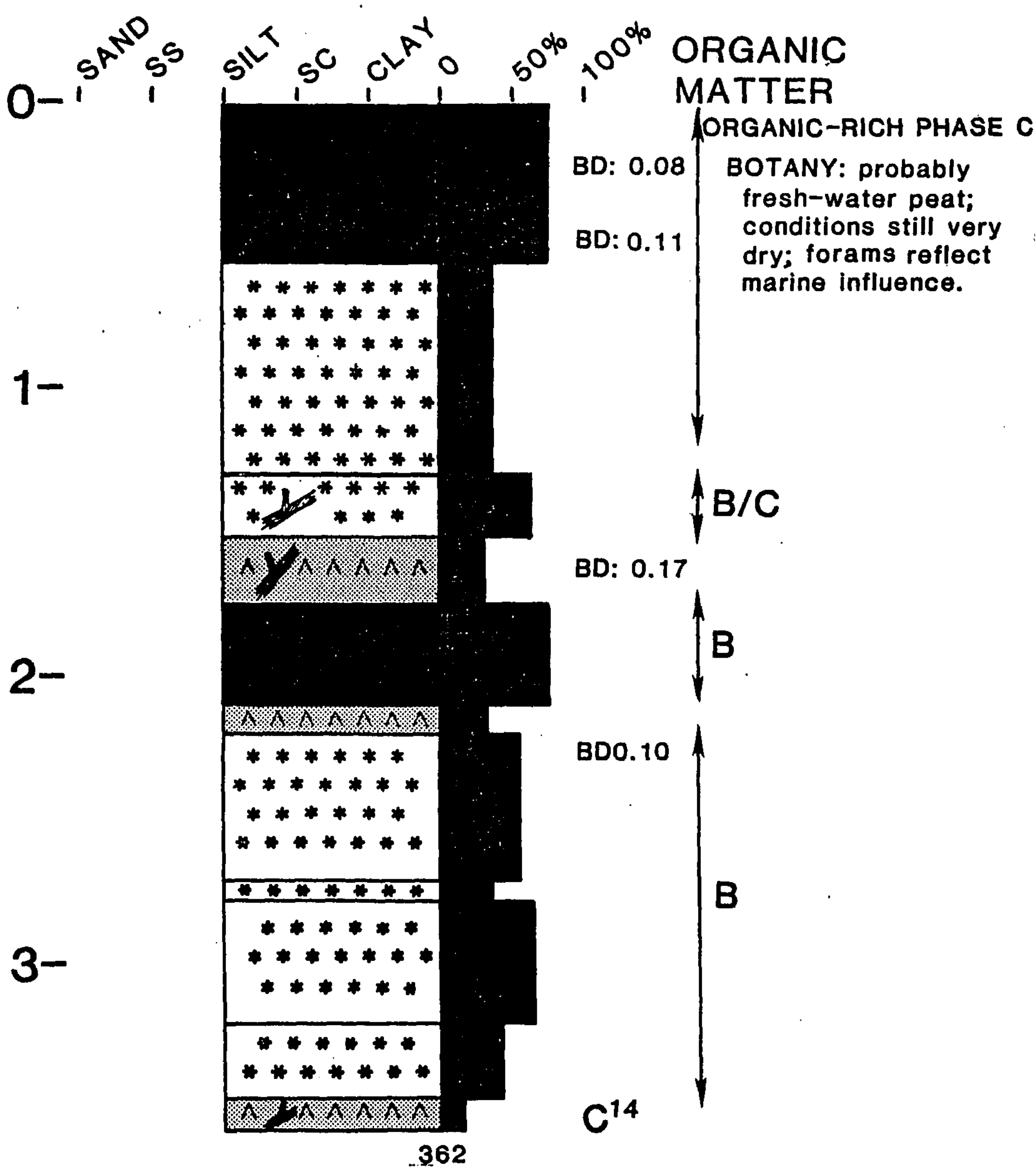
VIBRACORE BB20/106CM COMPACTION



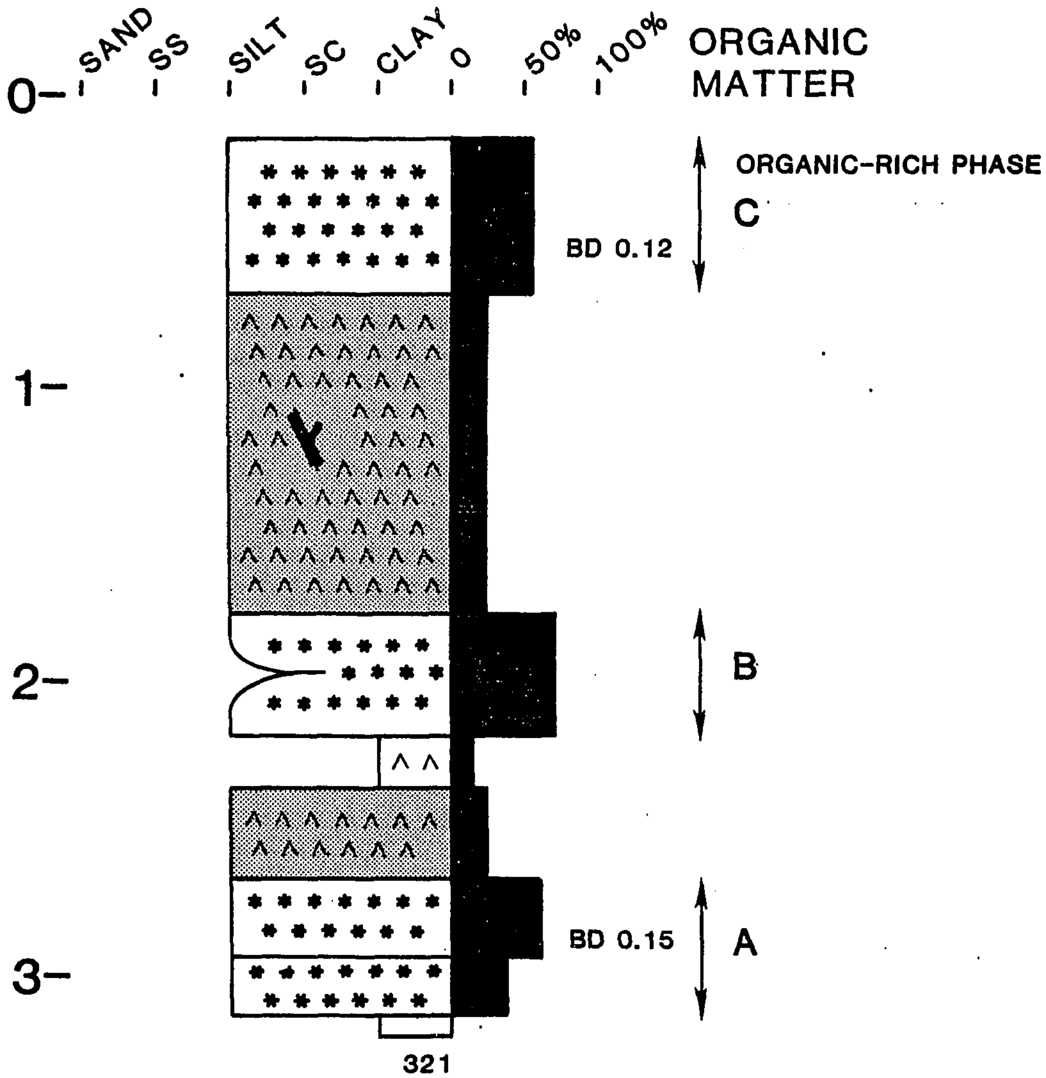
VIBRACORE BB21 / 54CM COMPACTION



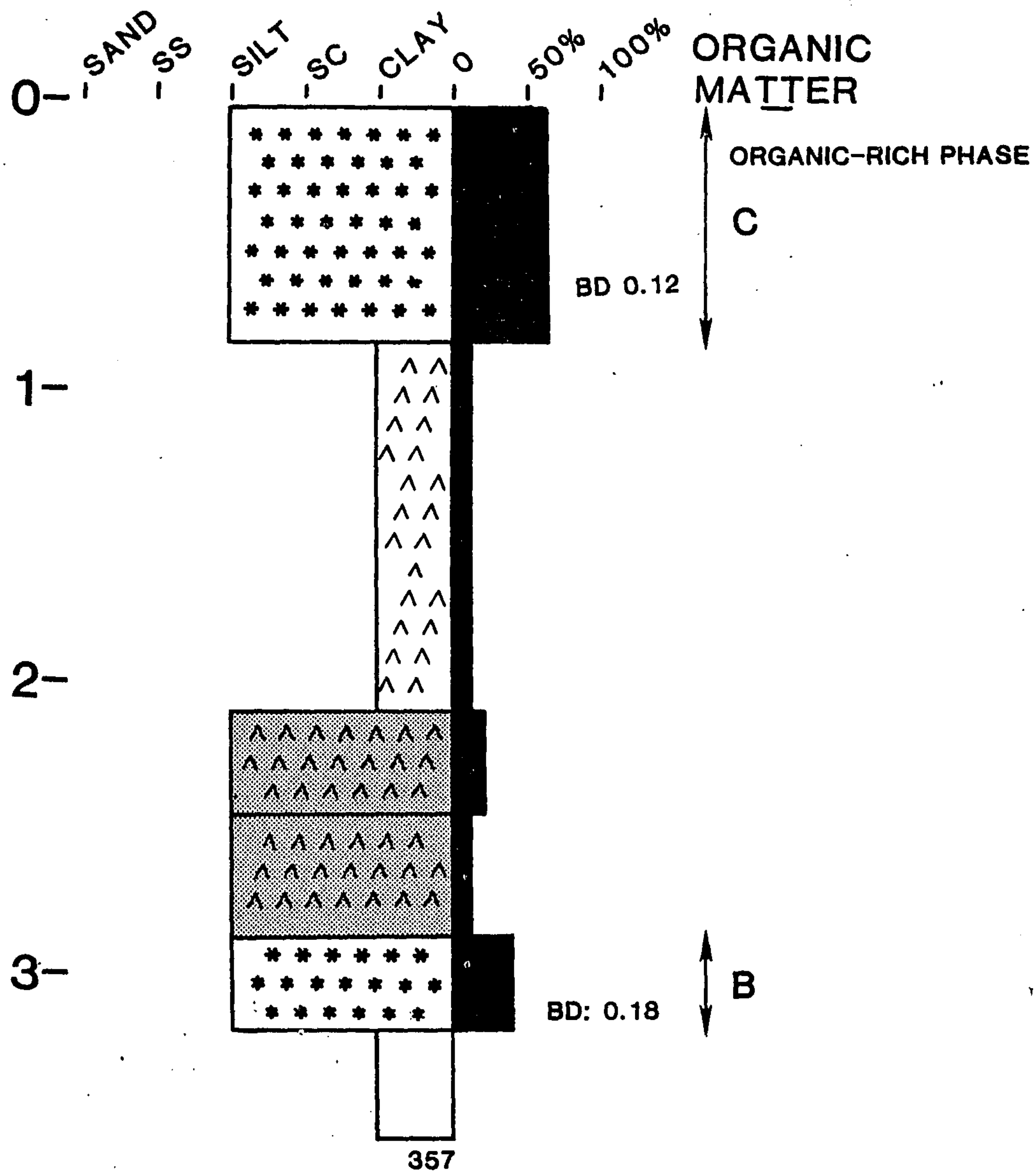
VIBRACORE BB22 / 52CM COMPACTION



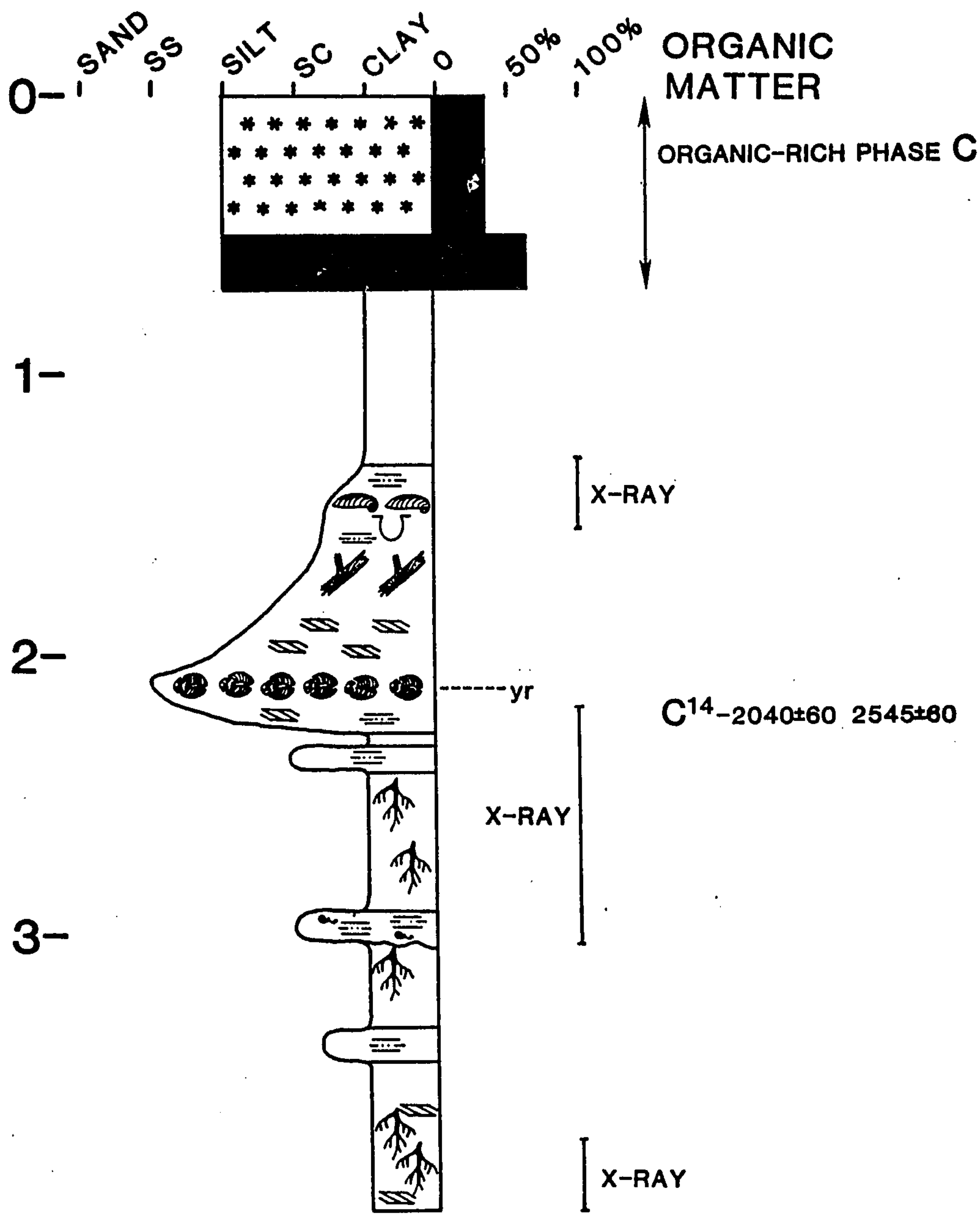
VIBRACORE BB23 / 80CM COMPACTION



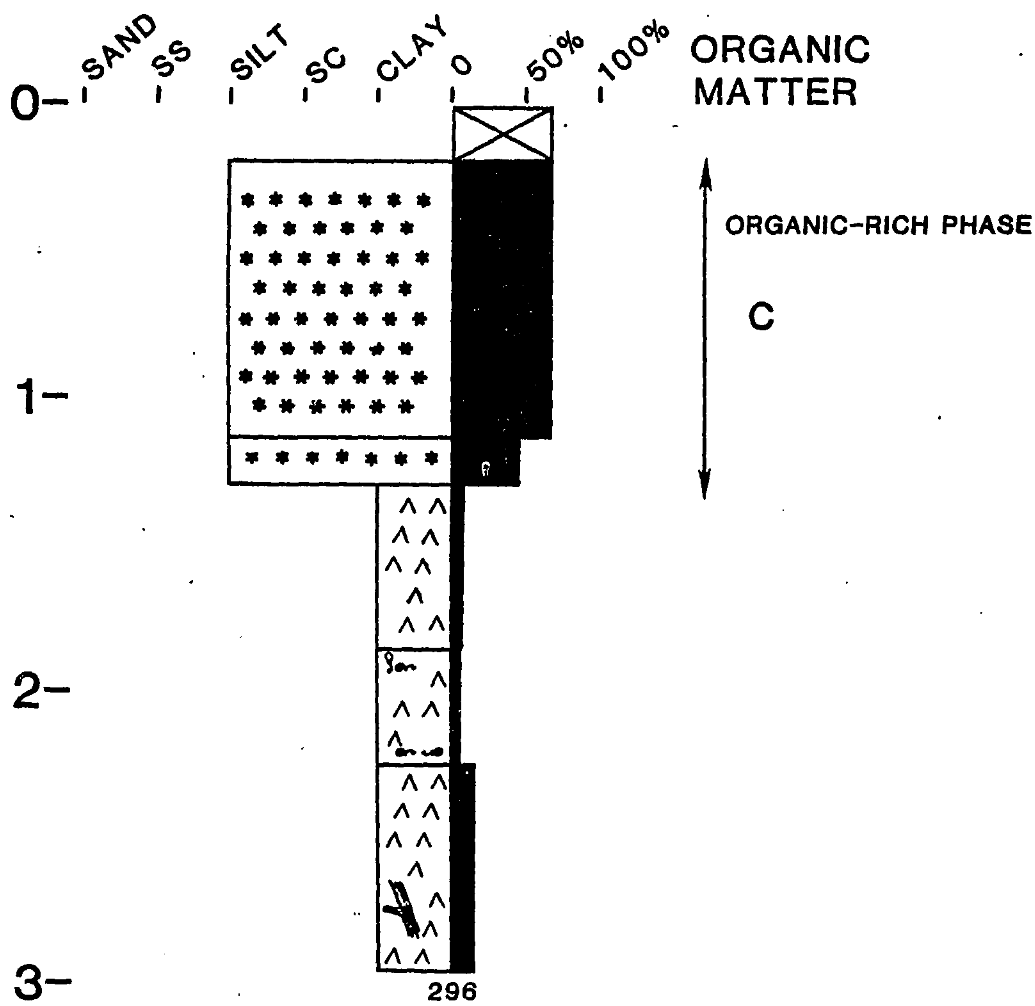
VIBRACORE BB24 / 36CM COMPACTION



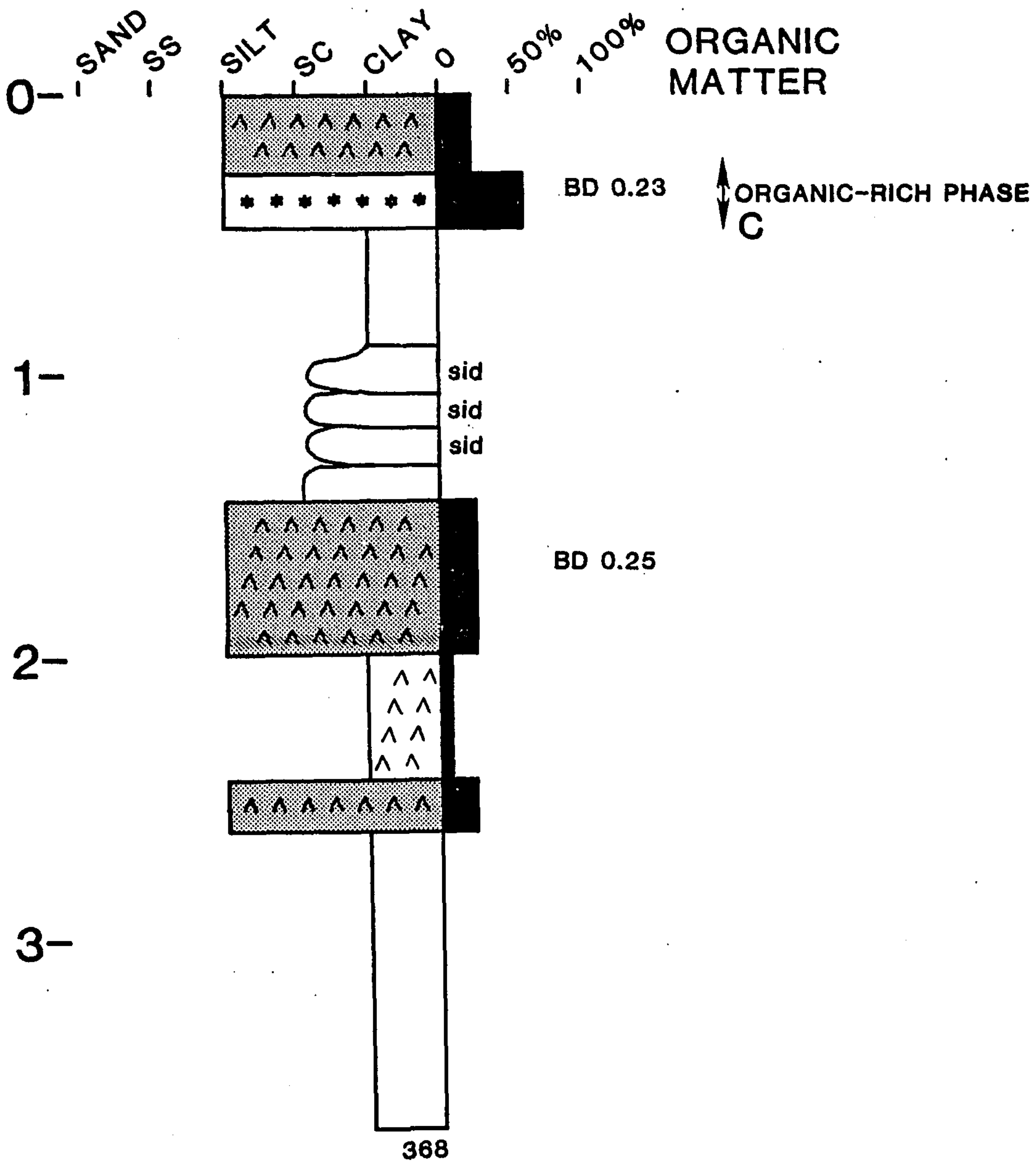
VIBRACORE BB 25 / 0 CM COMPACTION



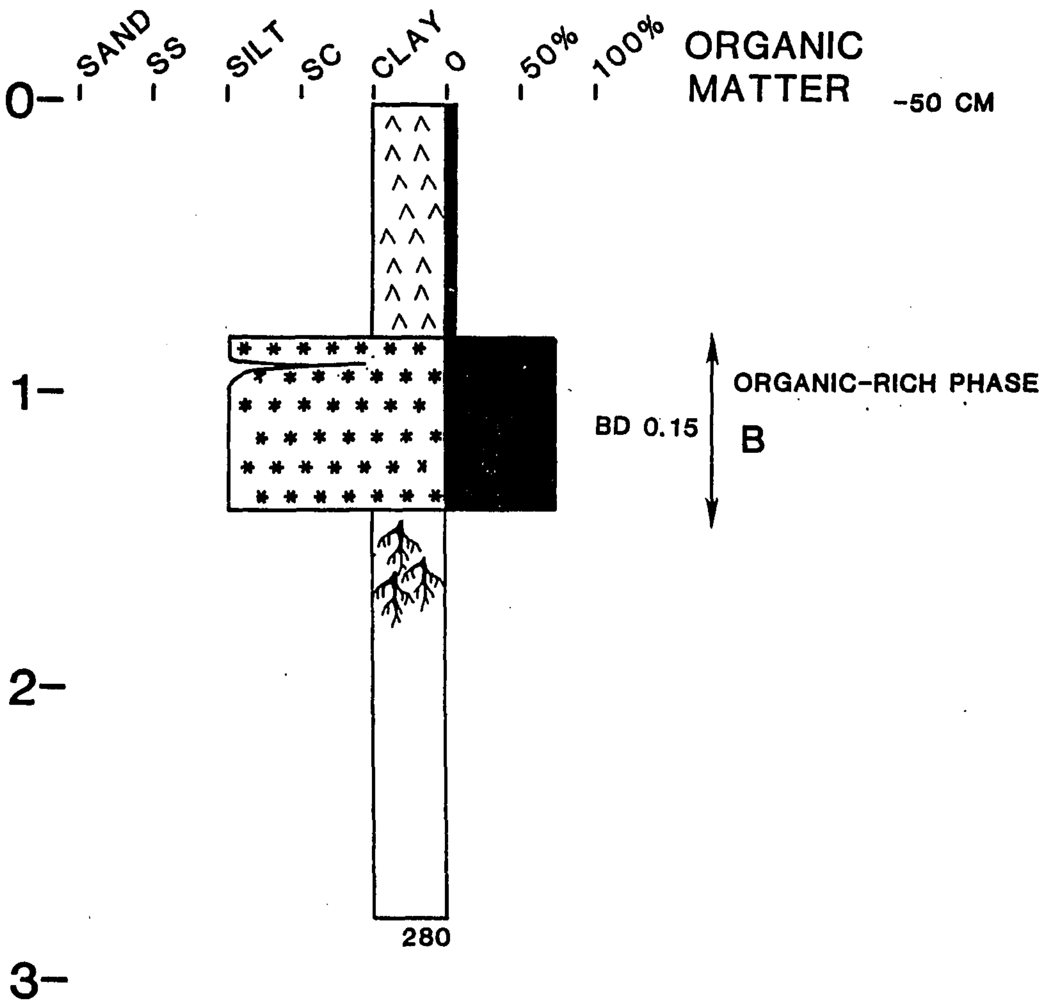
VIBRACORE BB26/106CM COMPACTION



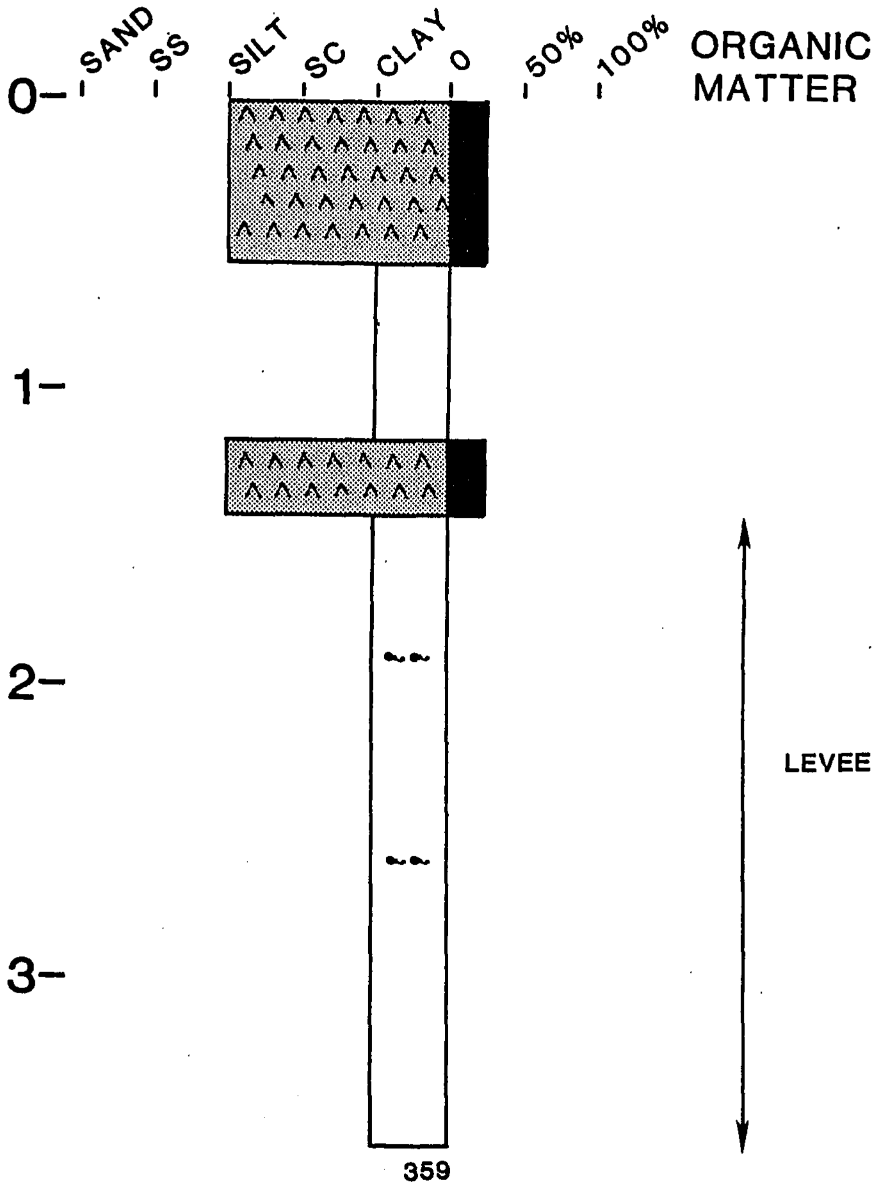
VIBRACORE BB27 / 101CM COMPACTION



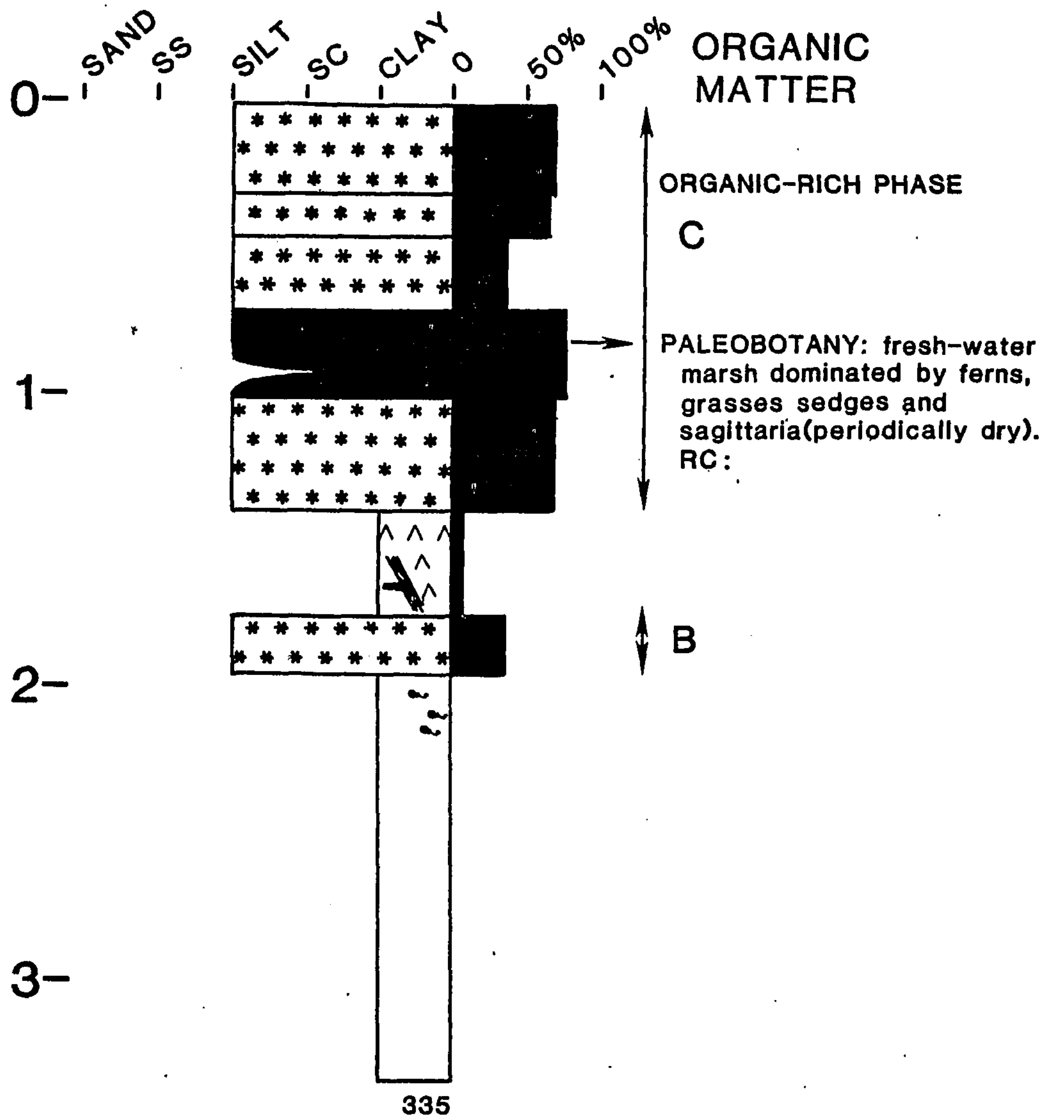
VIBRACORE BB28 / 10CM COMPACTION

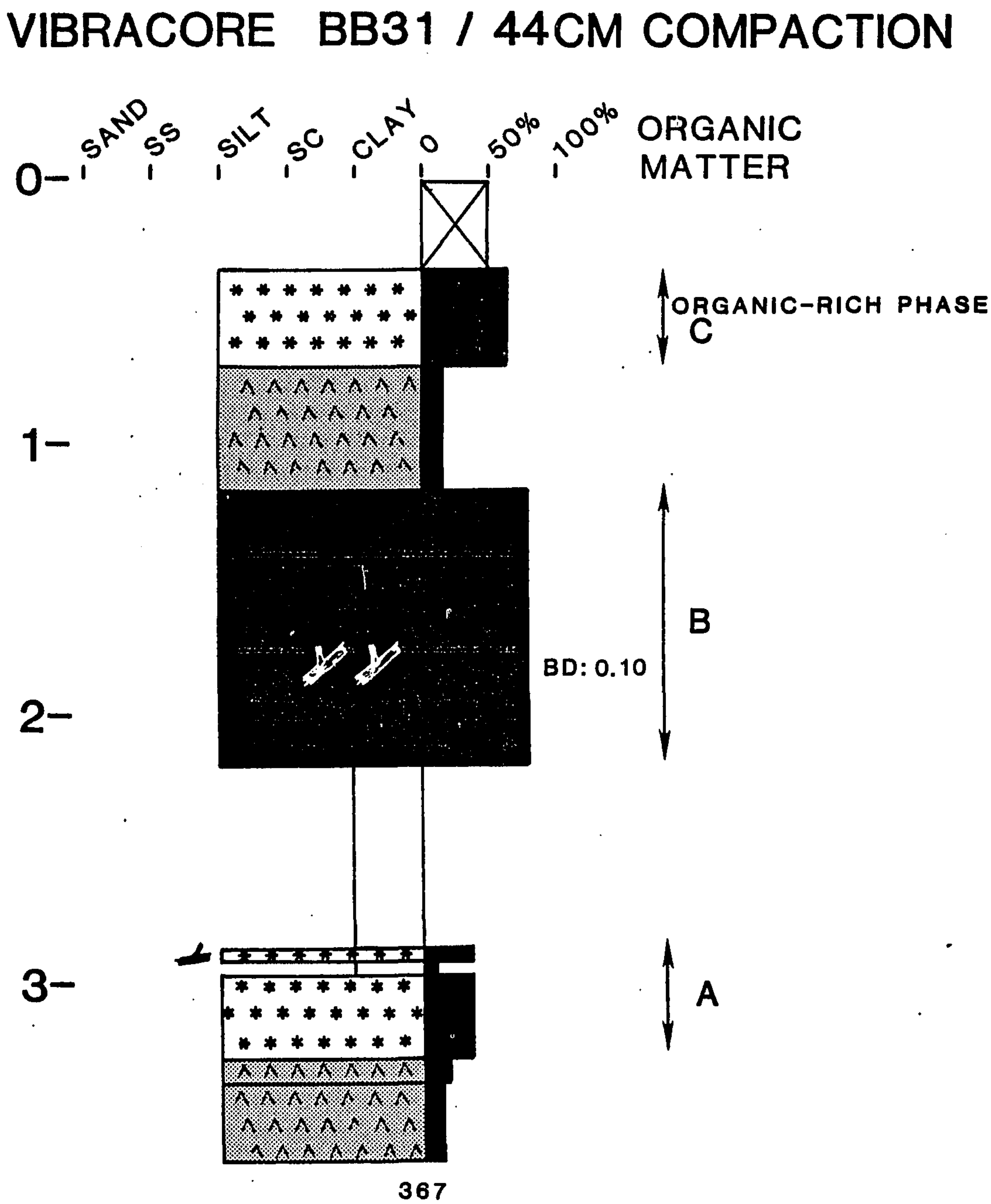


VIBRACORE BB29 / 50CM COMPACTION

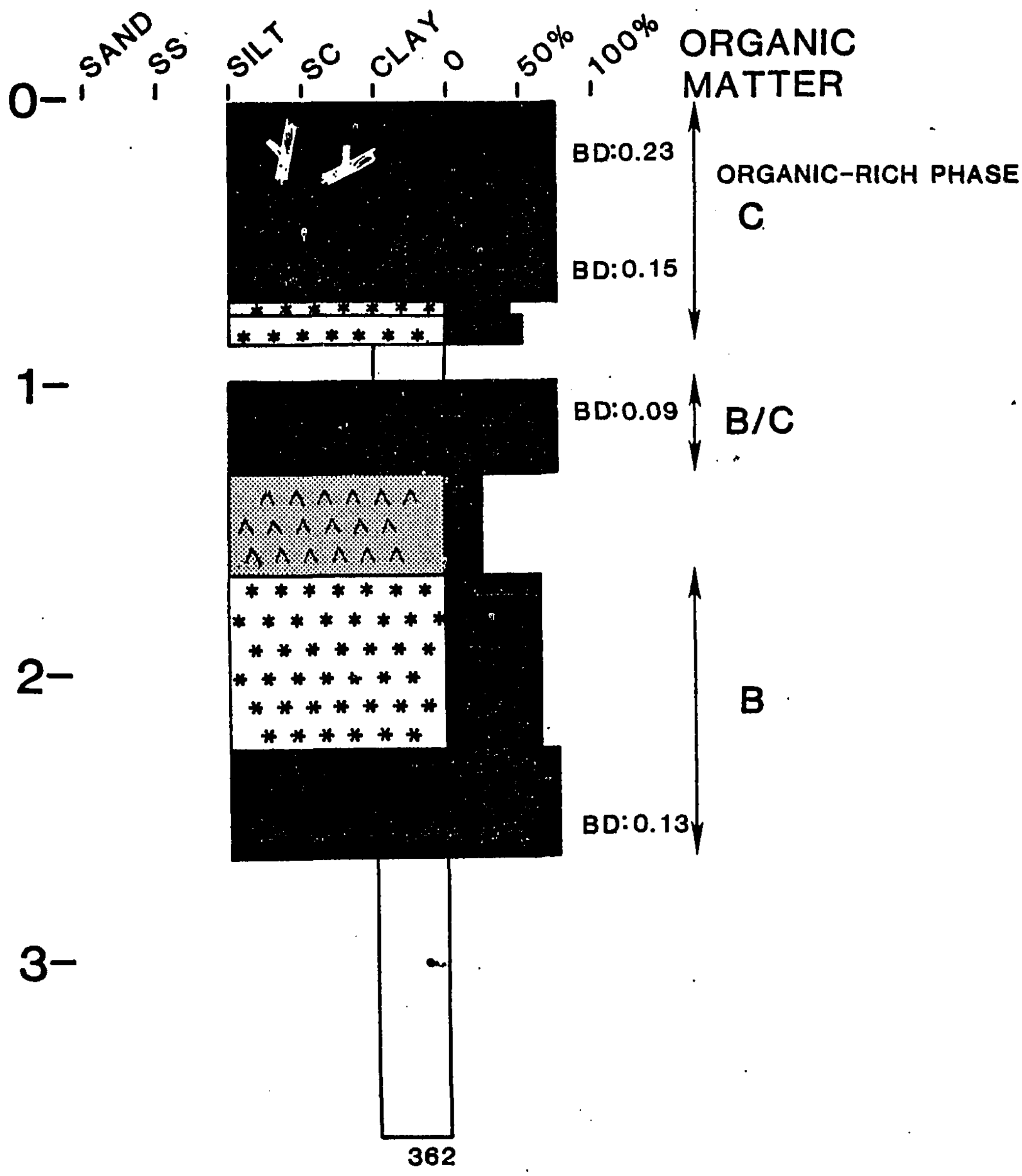


VIBRACORE BB30 / 76CM COMPACTION

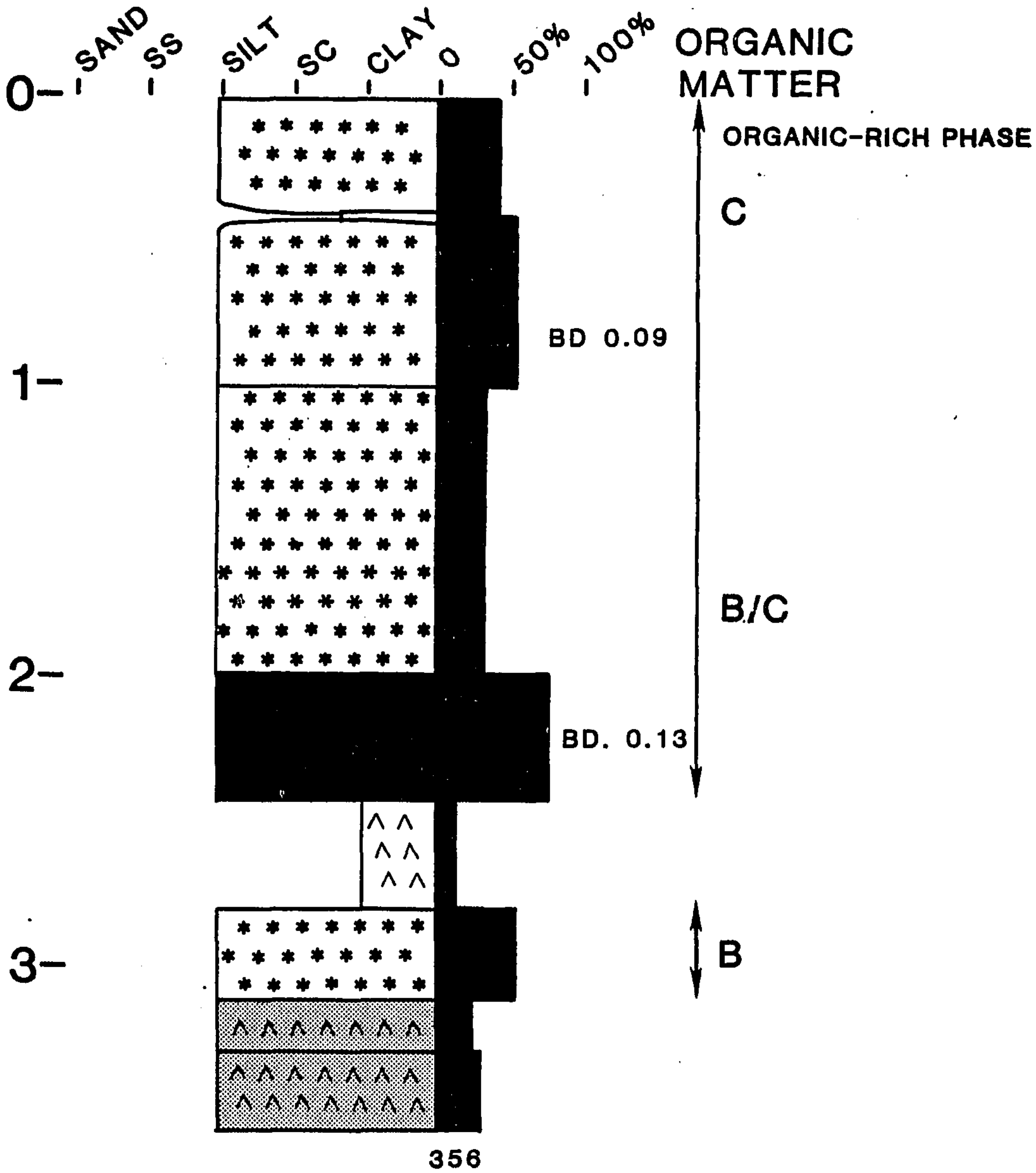



VIBRACORE BB31 / 44CM COMPACTION
SAND
SS
SILT
SC
CLAY
0
50%
100%
ORGANIC MATTER
0-
1-
2-
3-
ORGANIC-RICH PHASE
C
B
BD: 0.10
A
367

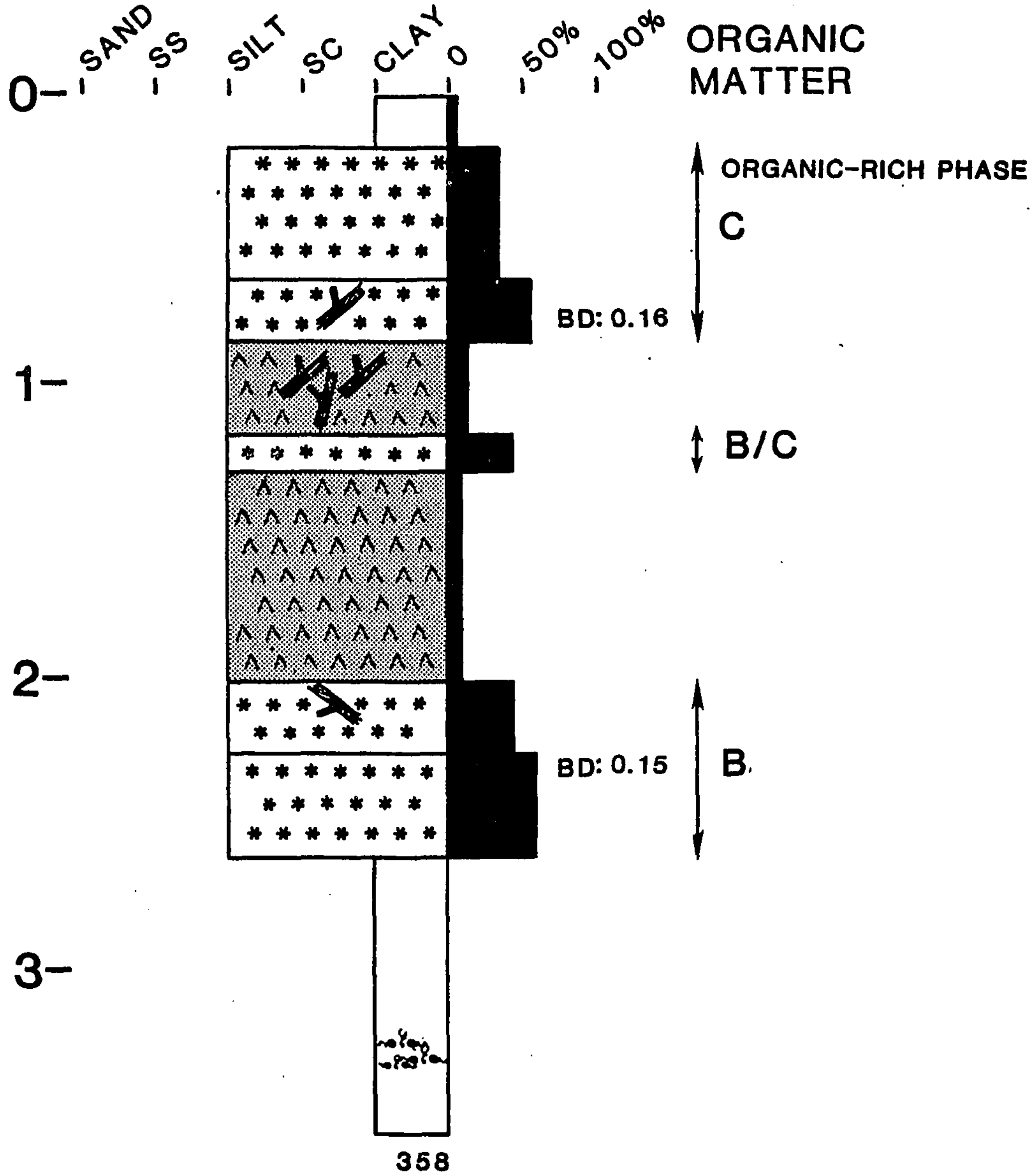
VIBRACORE BB32 / 4 CM COMPACTION



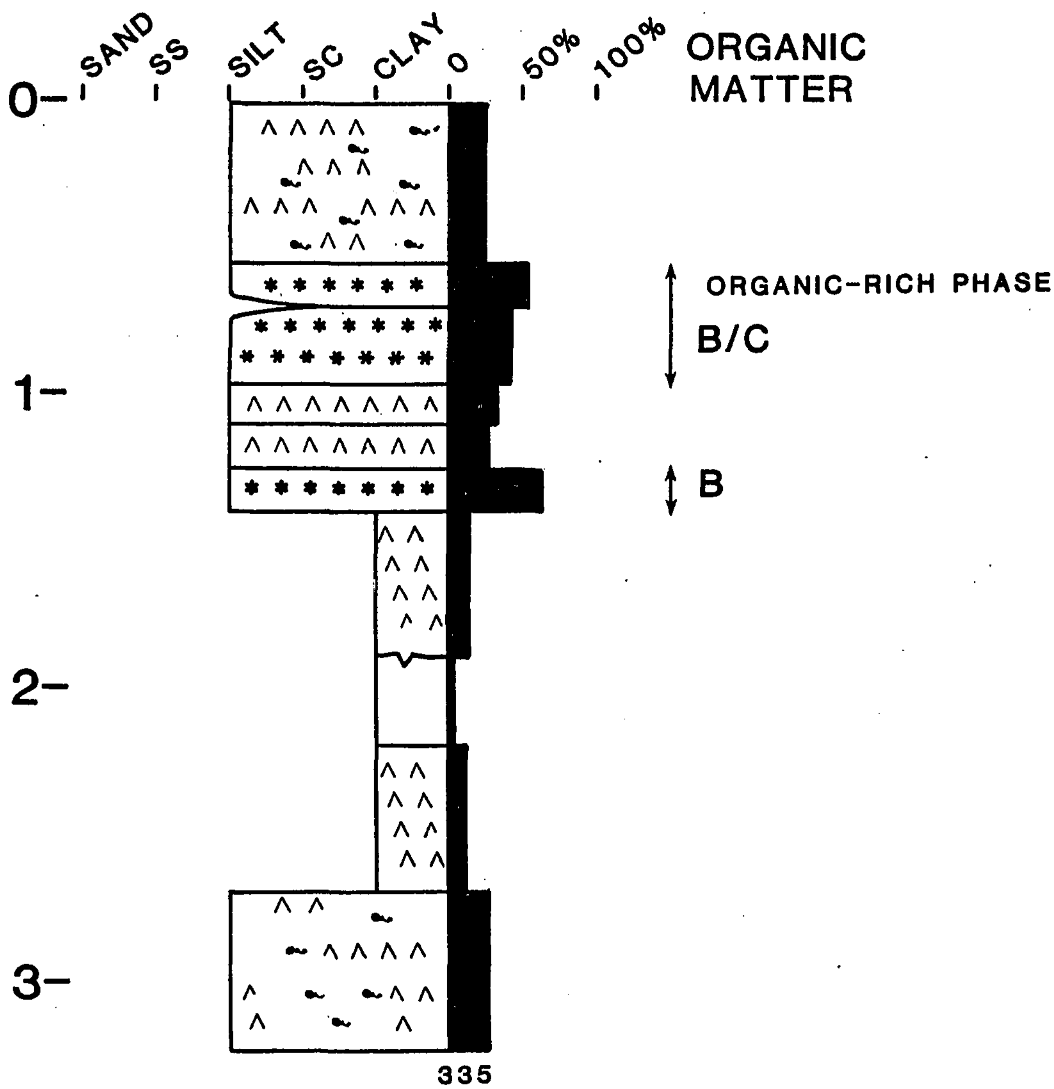
VIBRACORE BB33 / 60 CM COMPACTION



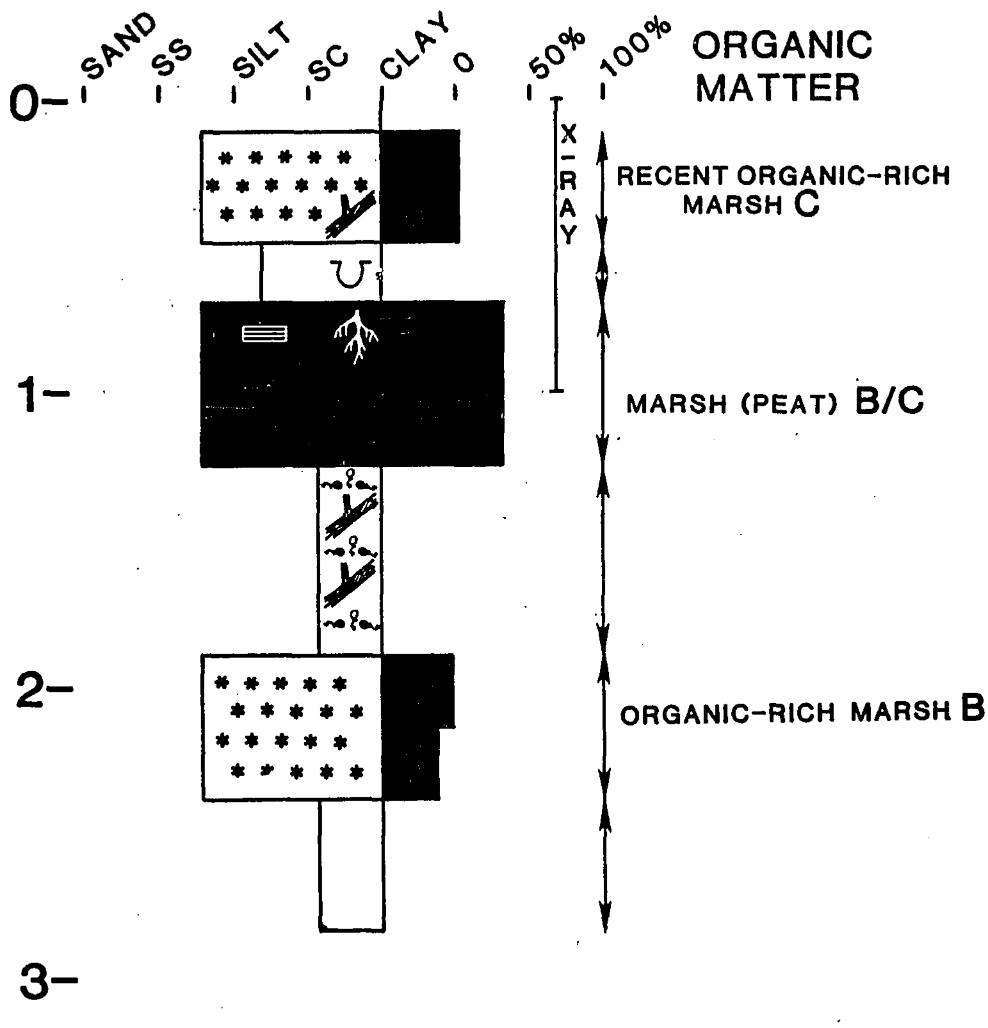
VIBRACORE BB34 / 12CM COMPACTION



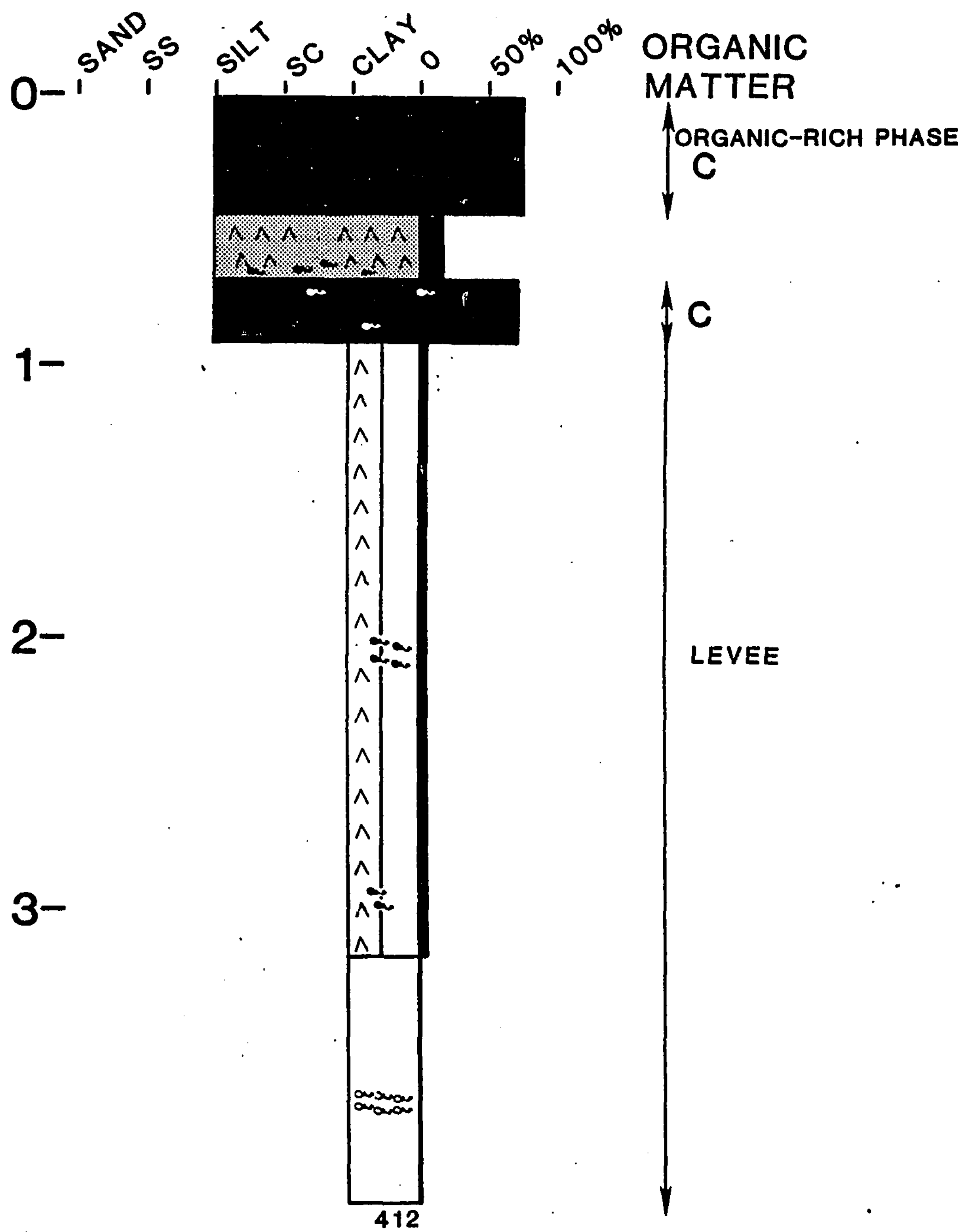
VIBRACORE BB35 / 84CM COMPACTION



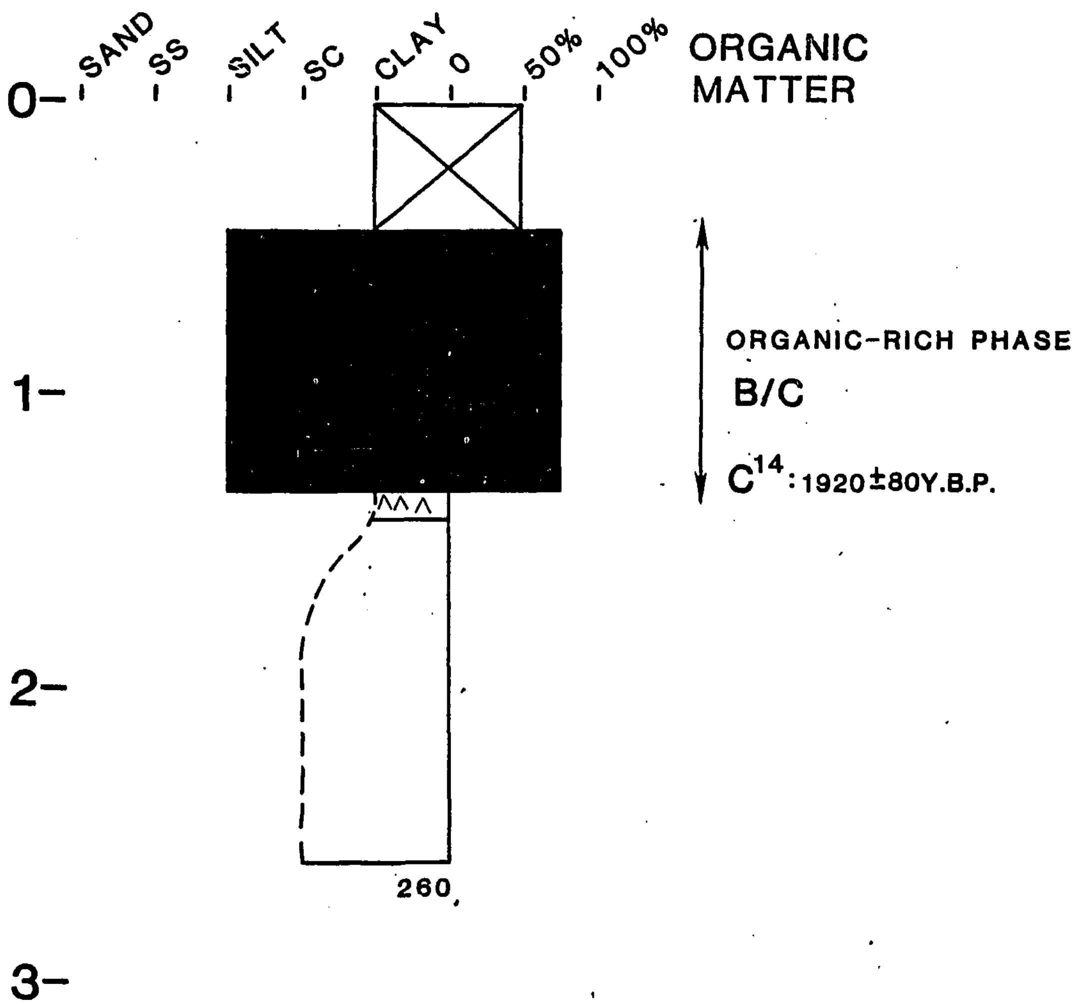
VIBRACORE BB36 / 12CM COMPACTION



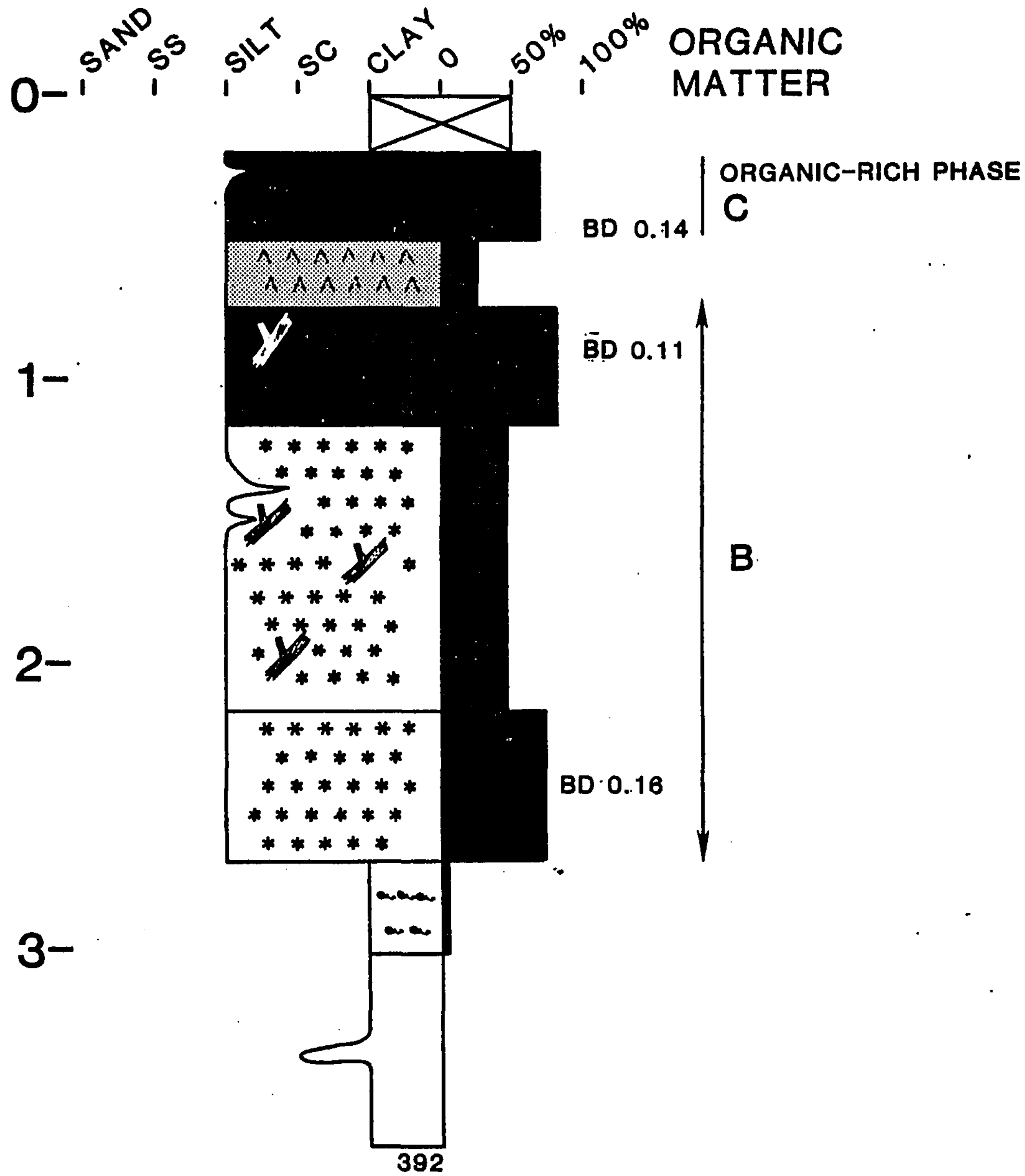
VIBRACORE BB38 / 42CM COMPACTION



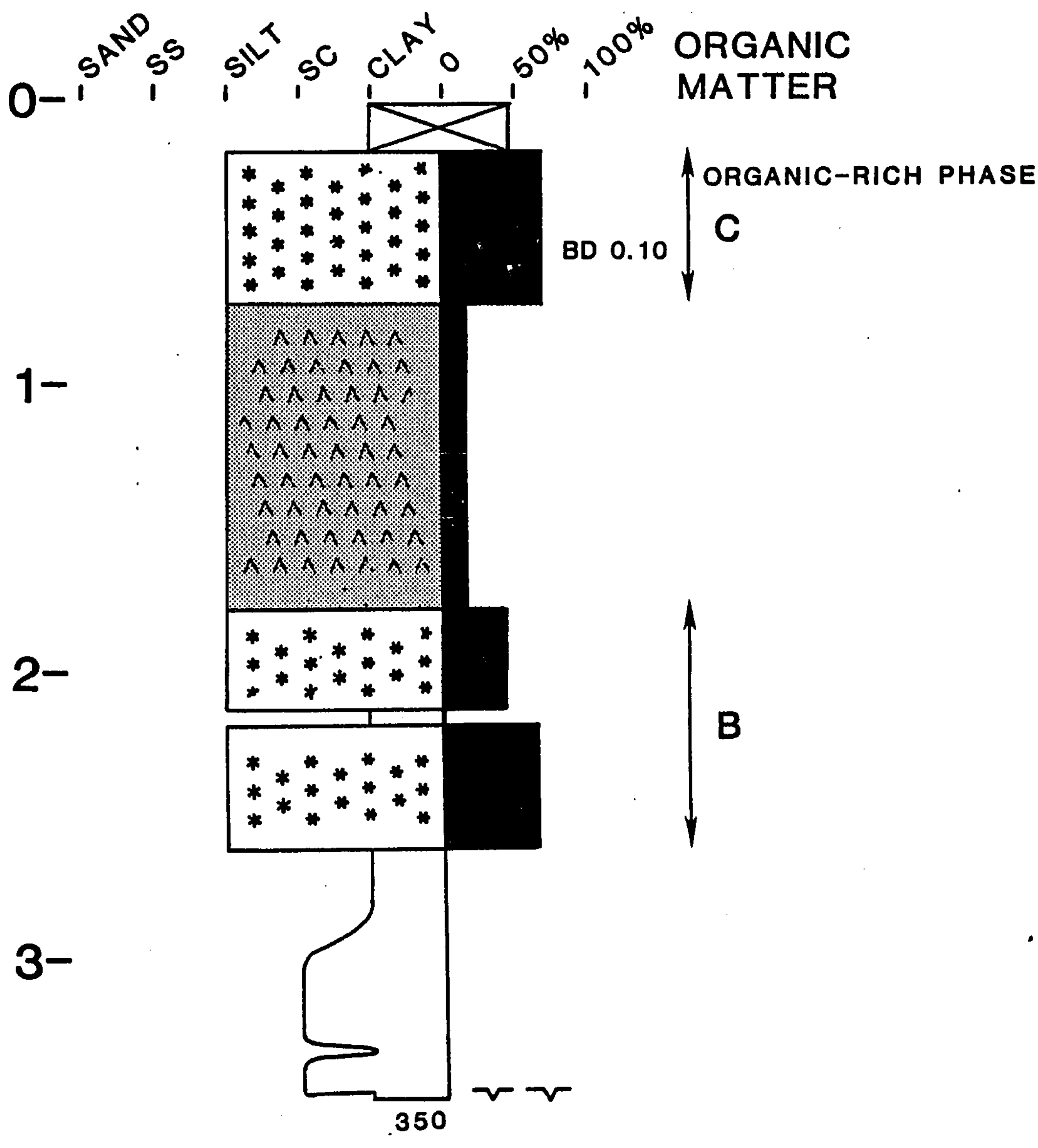
VIBRACORE BB40/150CM COMPACTION



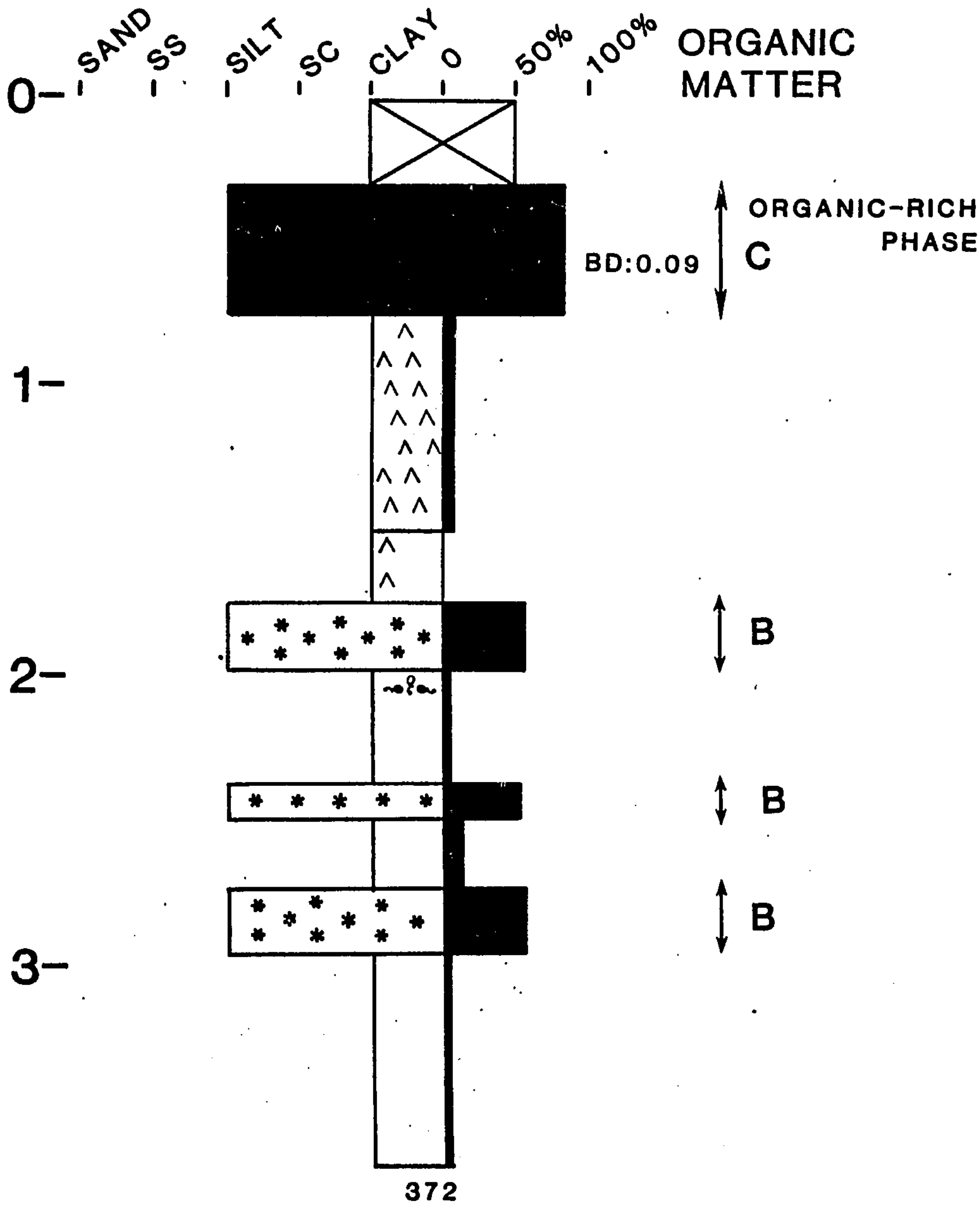
VIBRACORE BB41 / 42CM COMPACTION



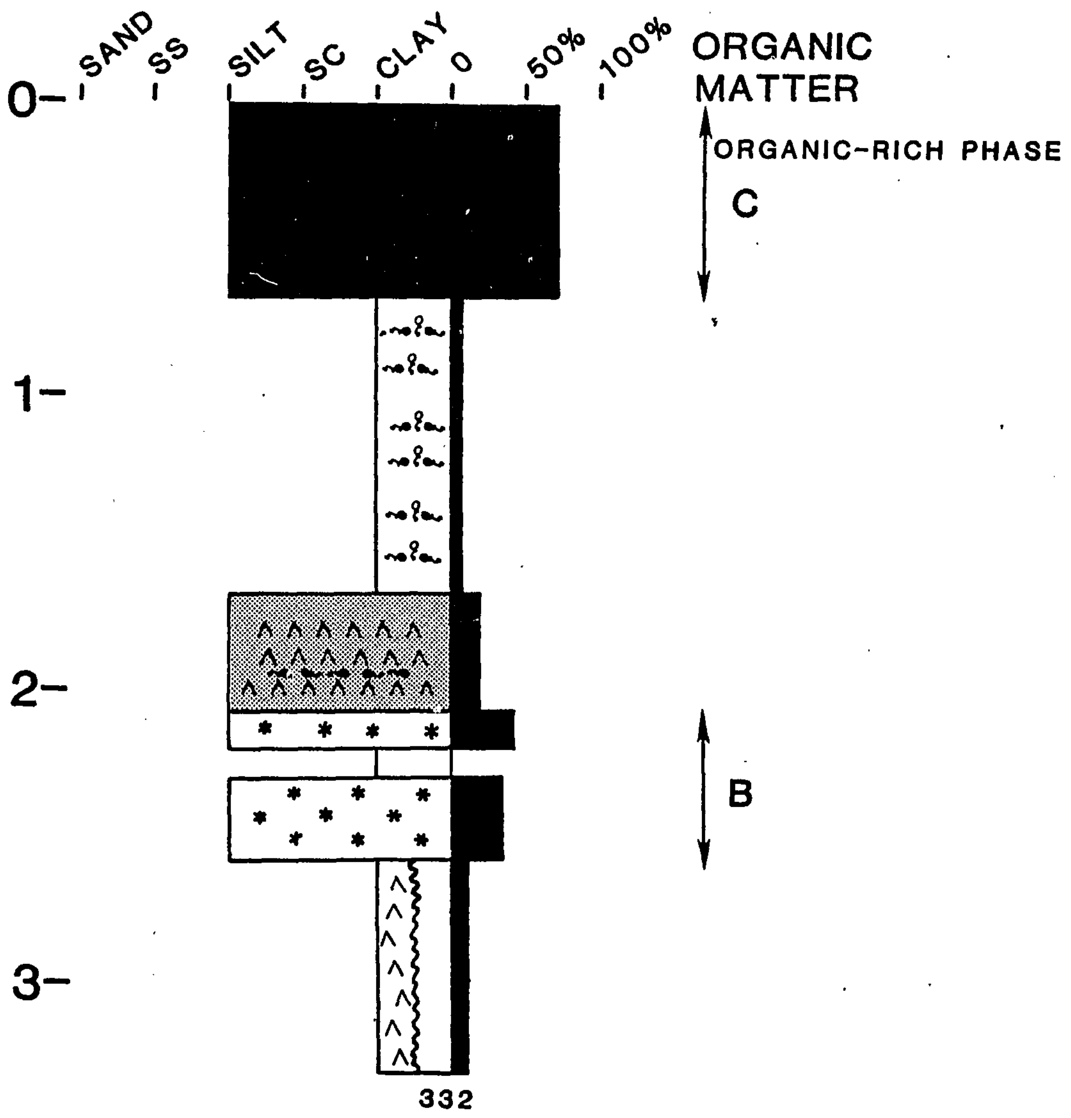
VIBRACORE BB42 / 74CM COMPACTION



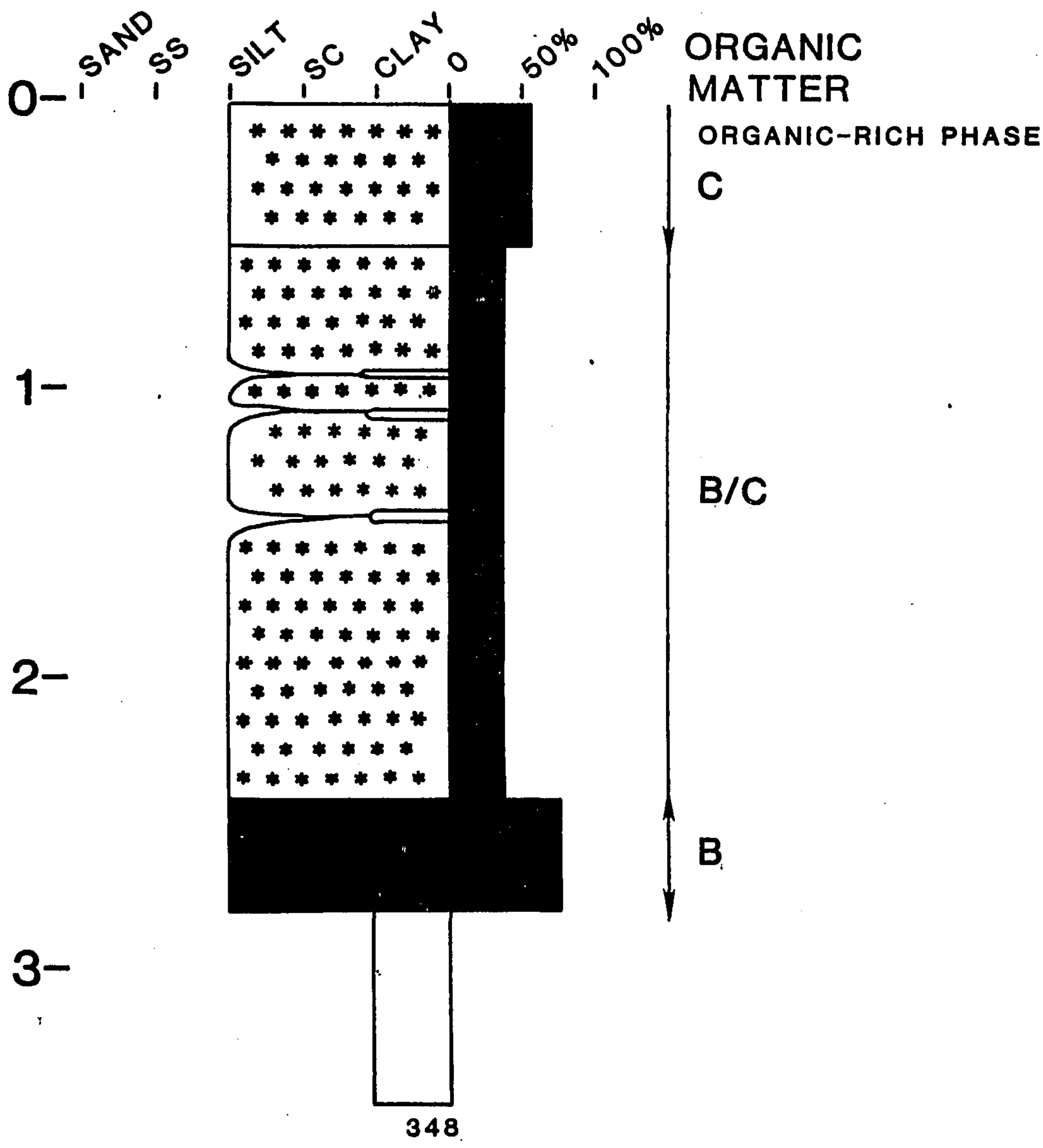
VIBRACORE BB43 / 47CM COMPACTION



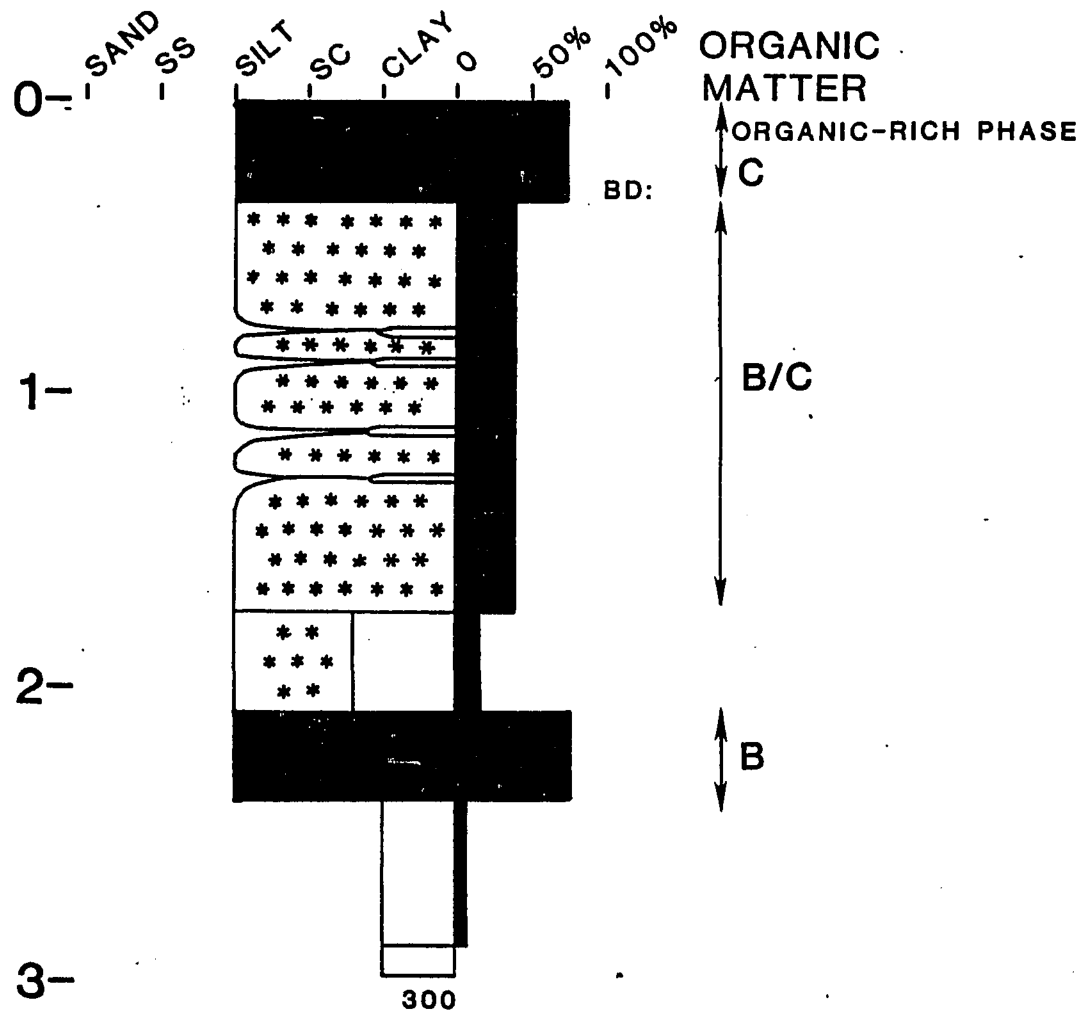
VIBRACORE BB44 / 44CM COMPACTION



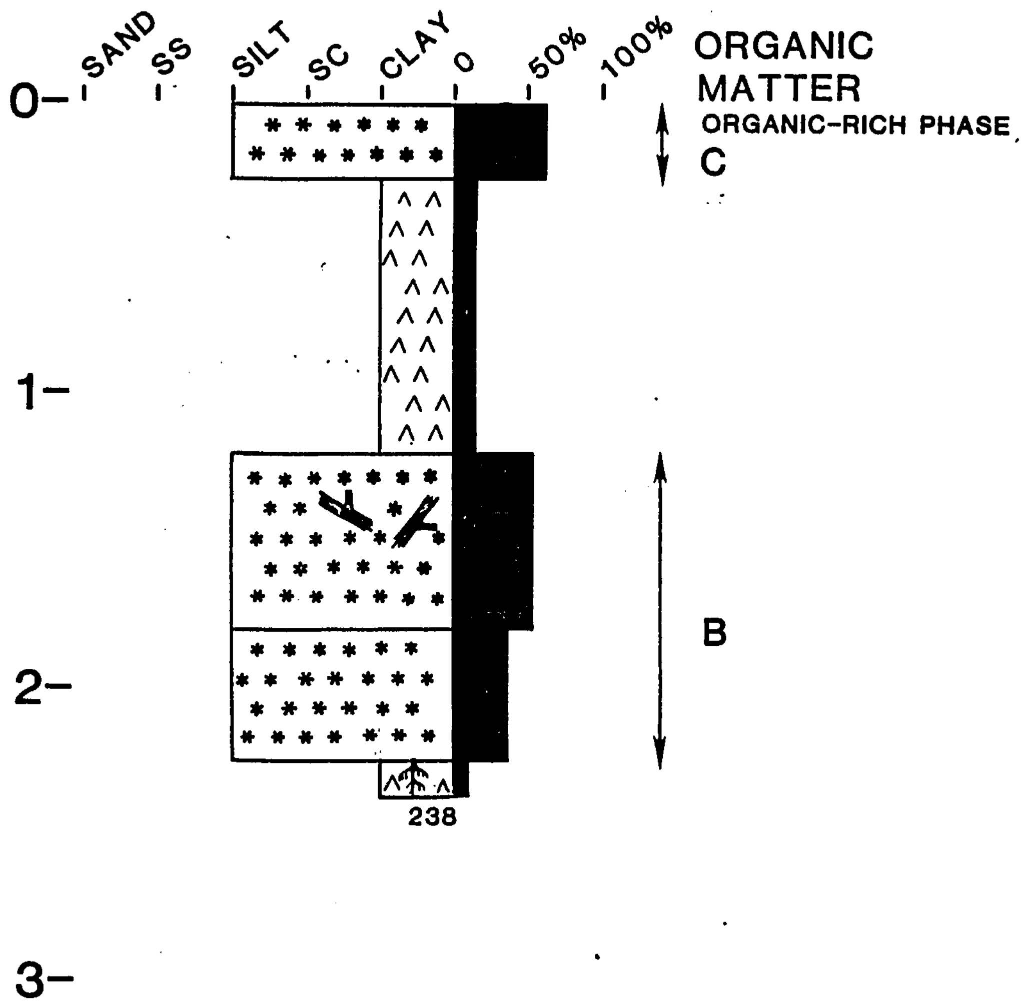
VIBRACORE BB45 / 42CM COMPACTION



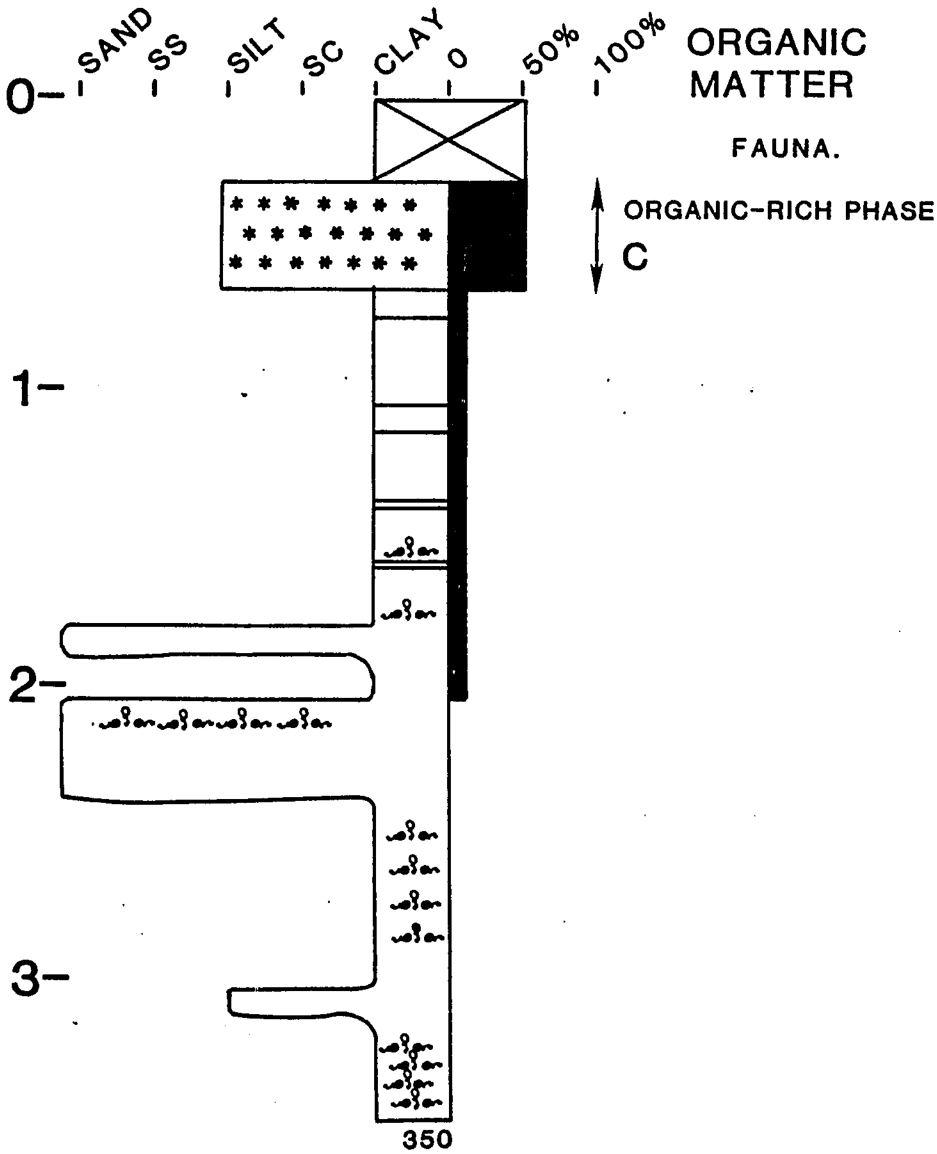
VIBRACORE BB46/114CM COMPACTION



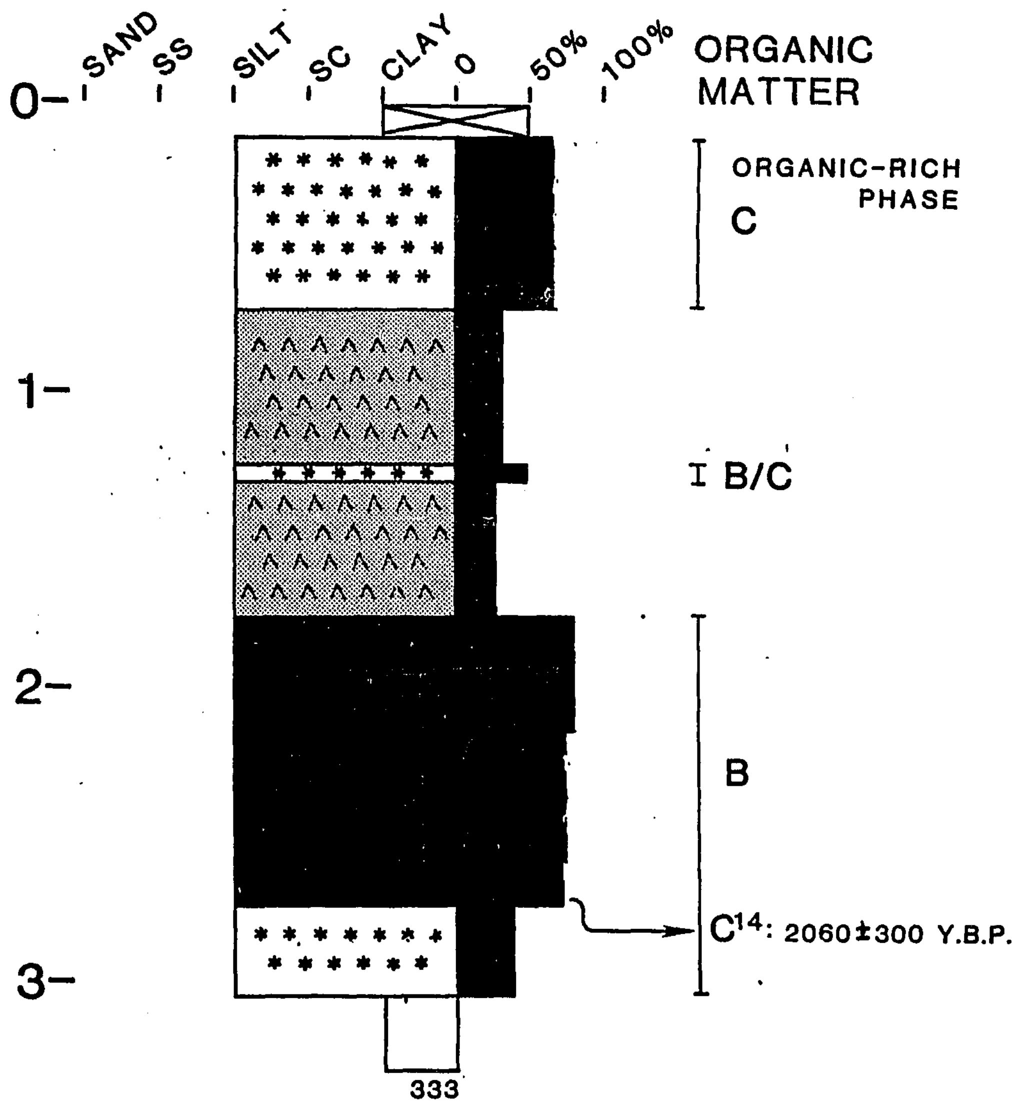
VIBRACORE BB47/188CM COMPACTION



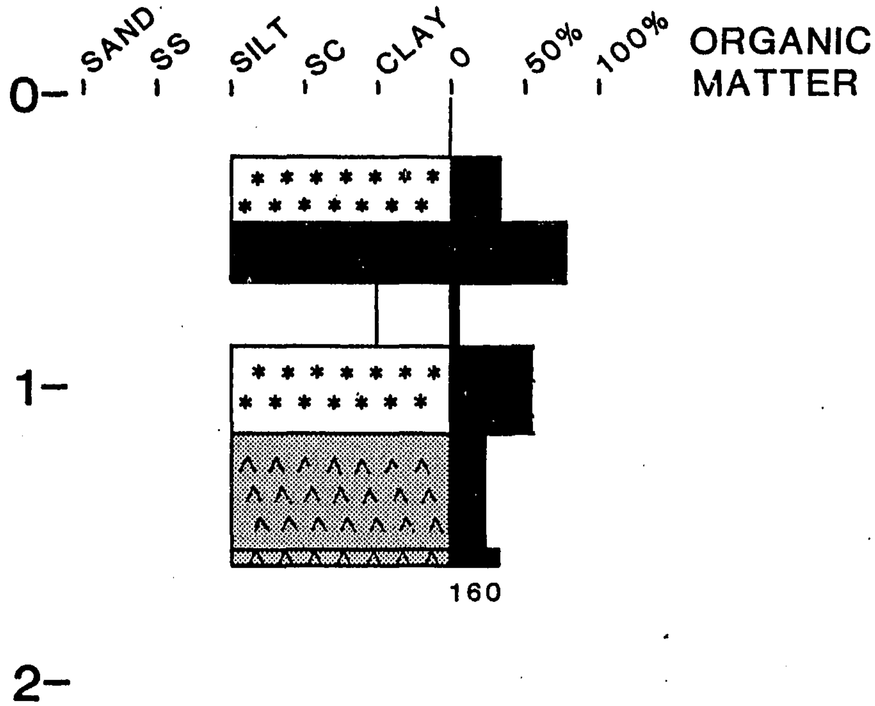
VIBRACORE BB48 / 50CM COMPACTION



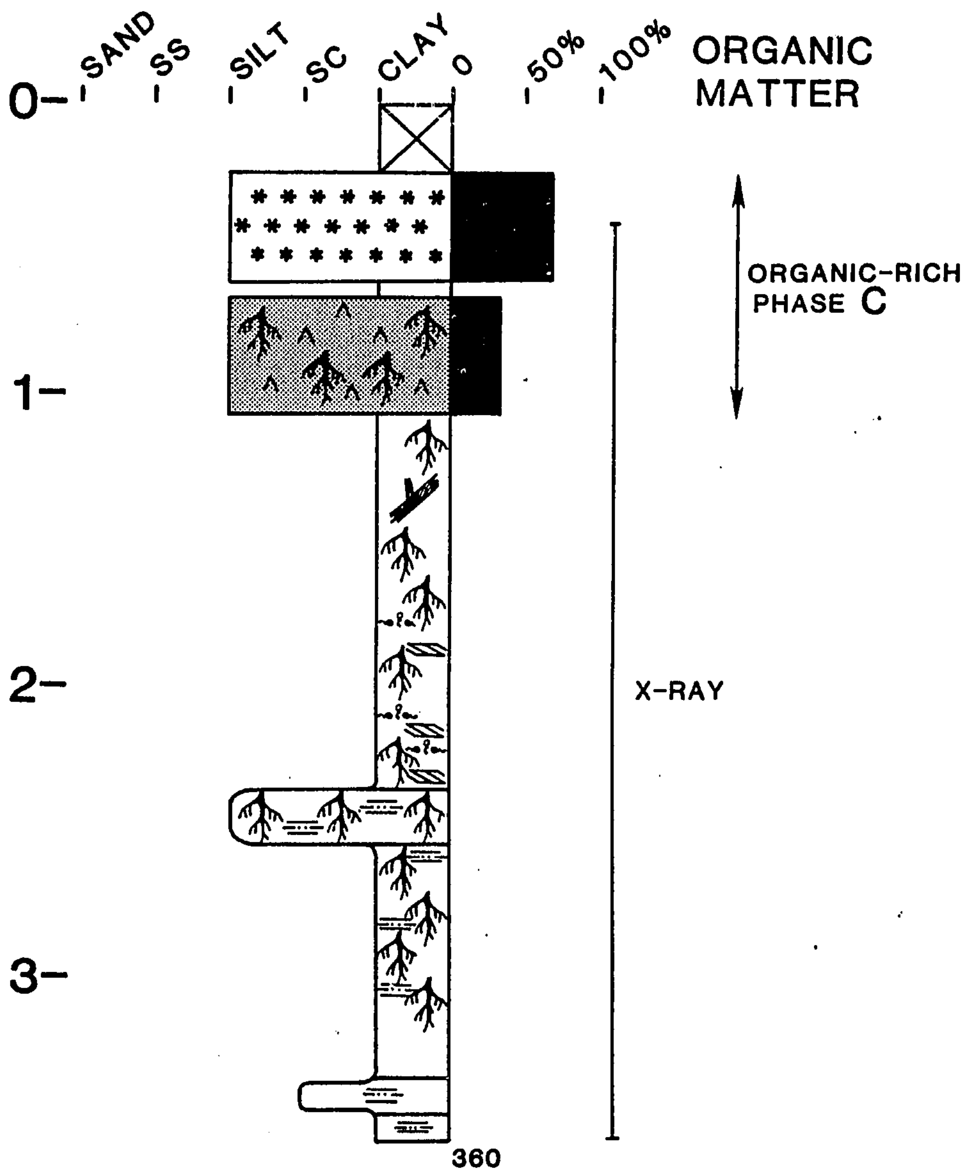
VIBRACORE BB49 / 72CM COMPACTION



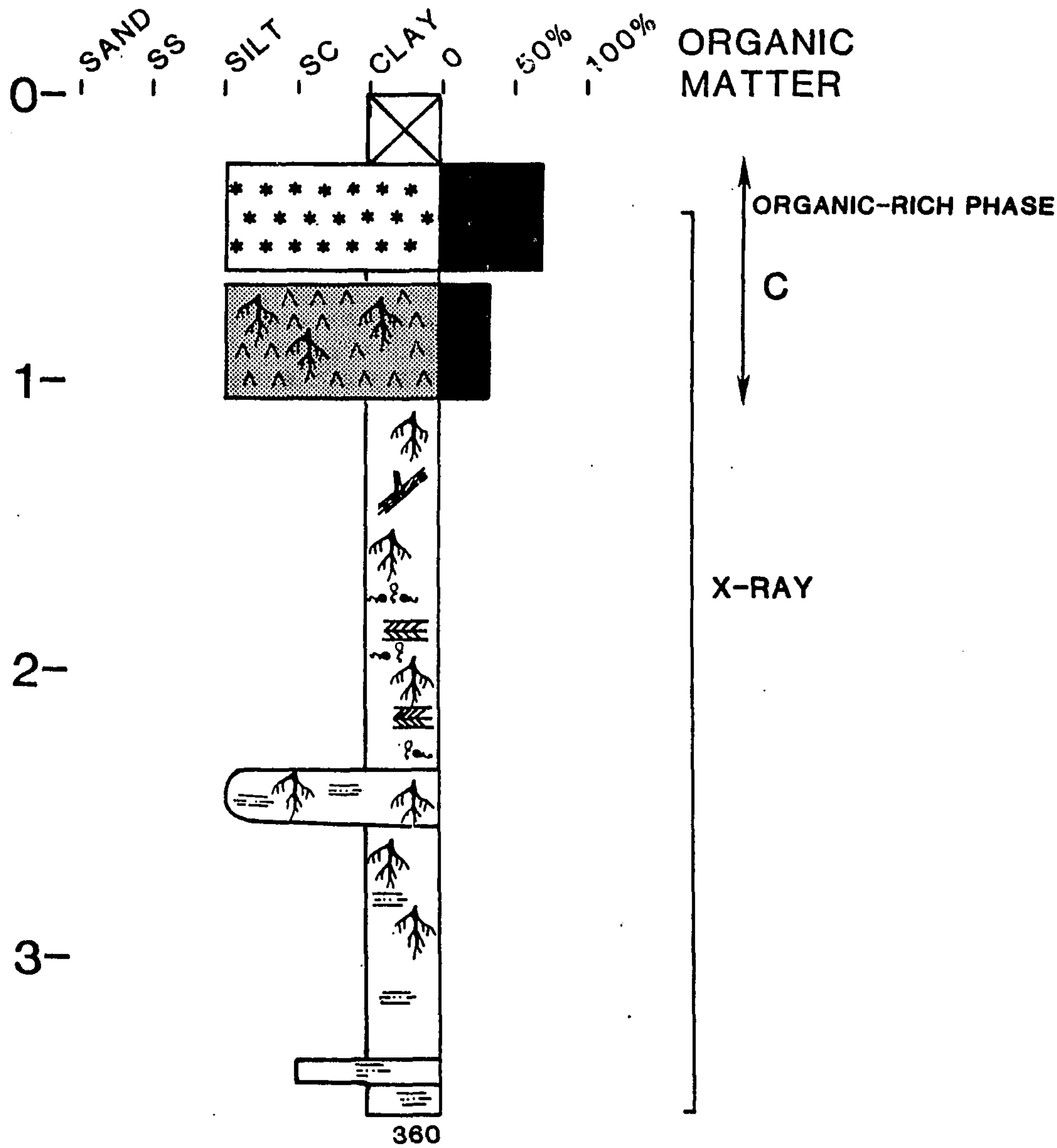
VIBRACORE BB50/256CM COMPACTION



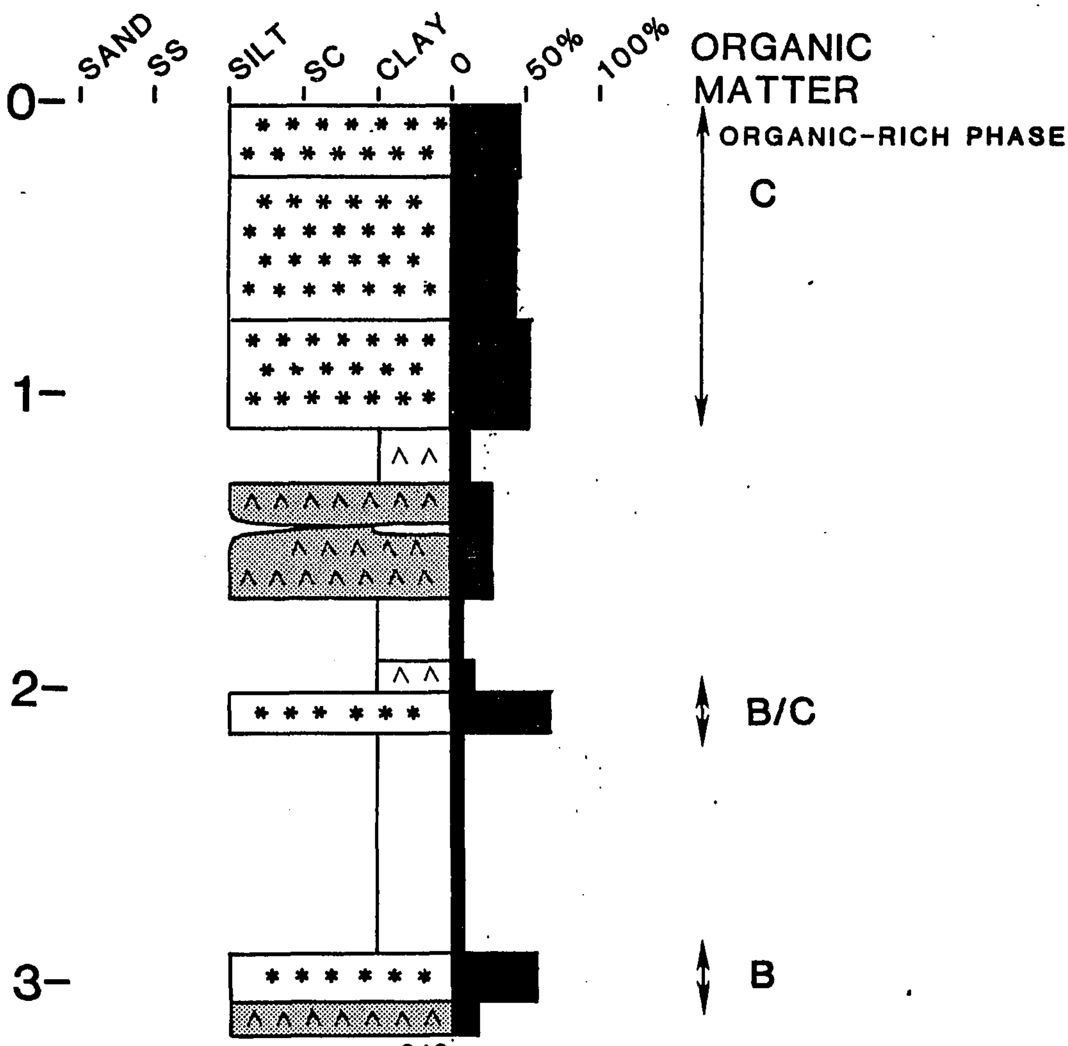
VIBRACORE BB 51 / 56CM COMPACTION



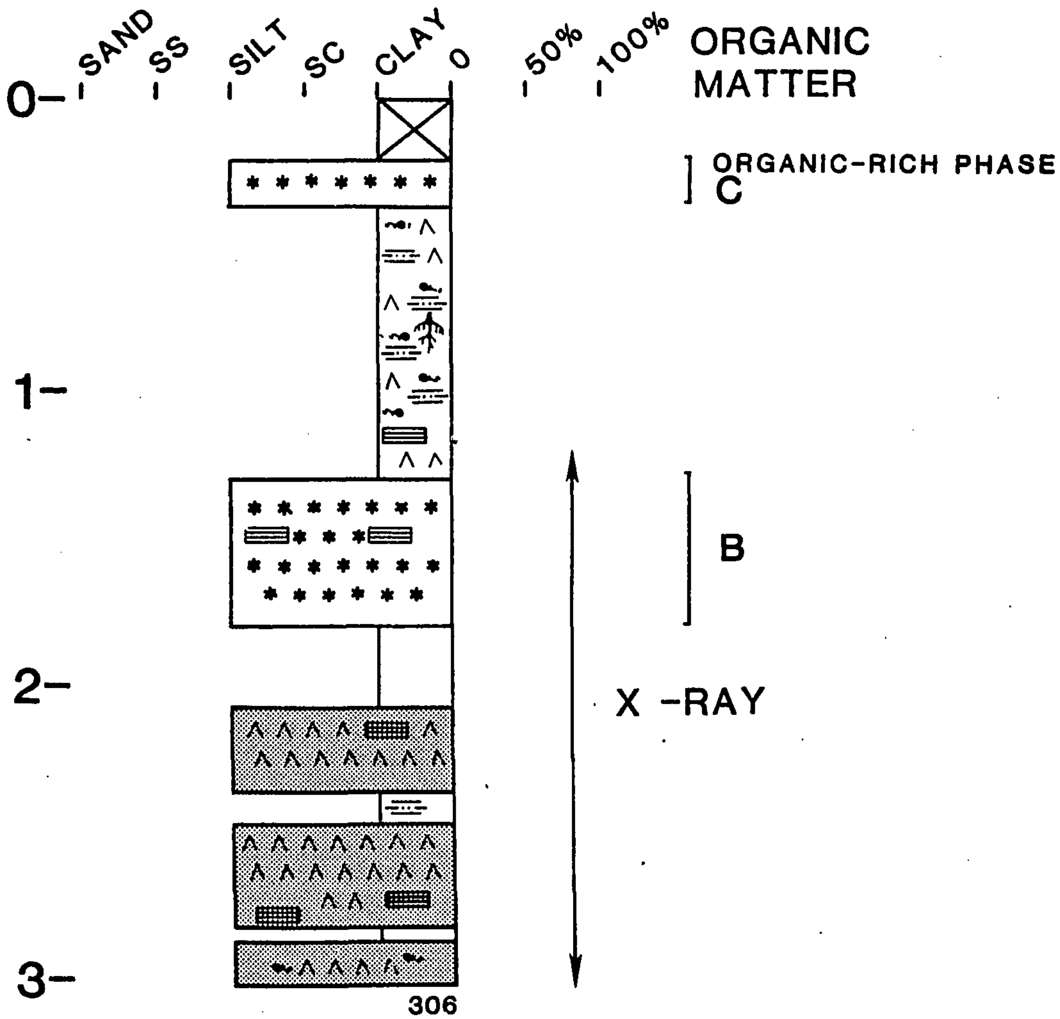
VIBRACORE BB 51 / 56 CM COMPACTION



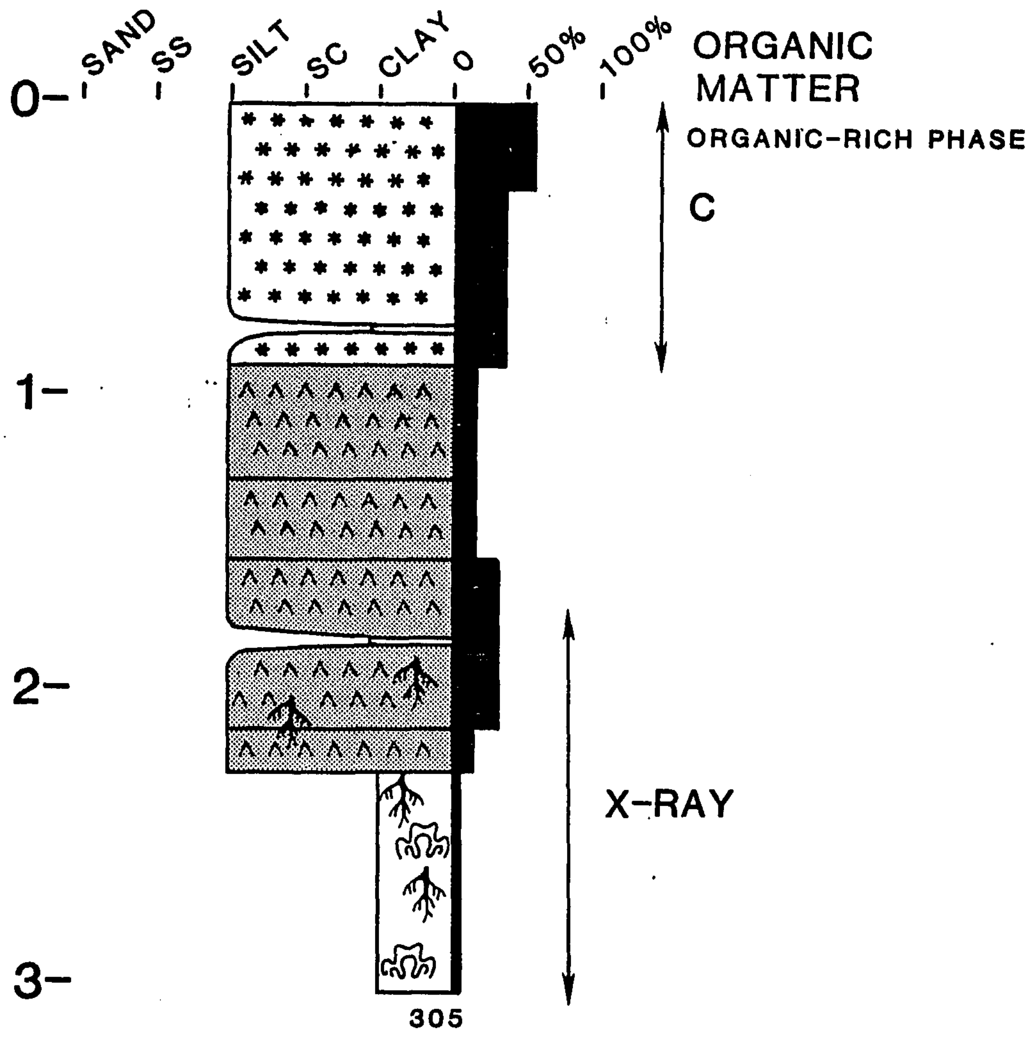
VIBRACORE BB52/100CM COMPACTION



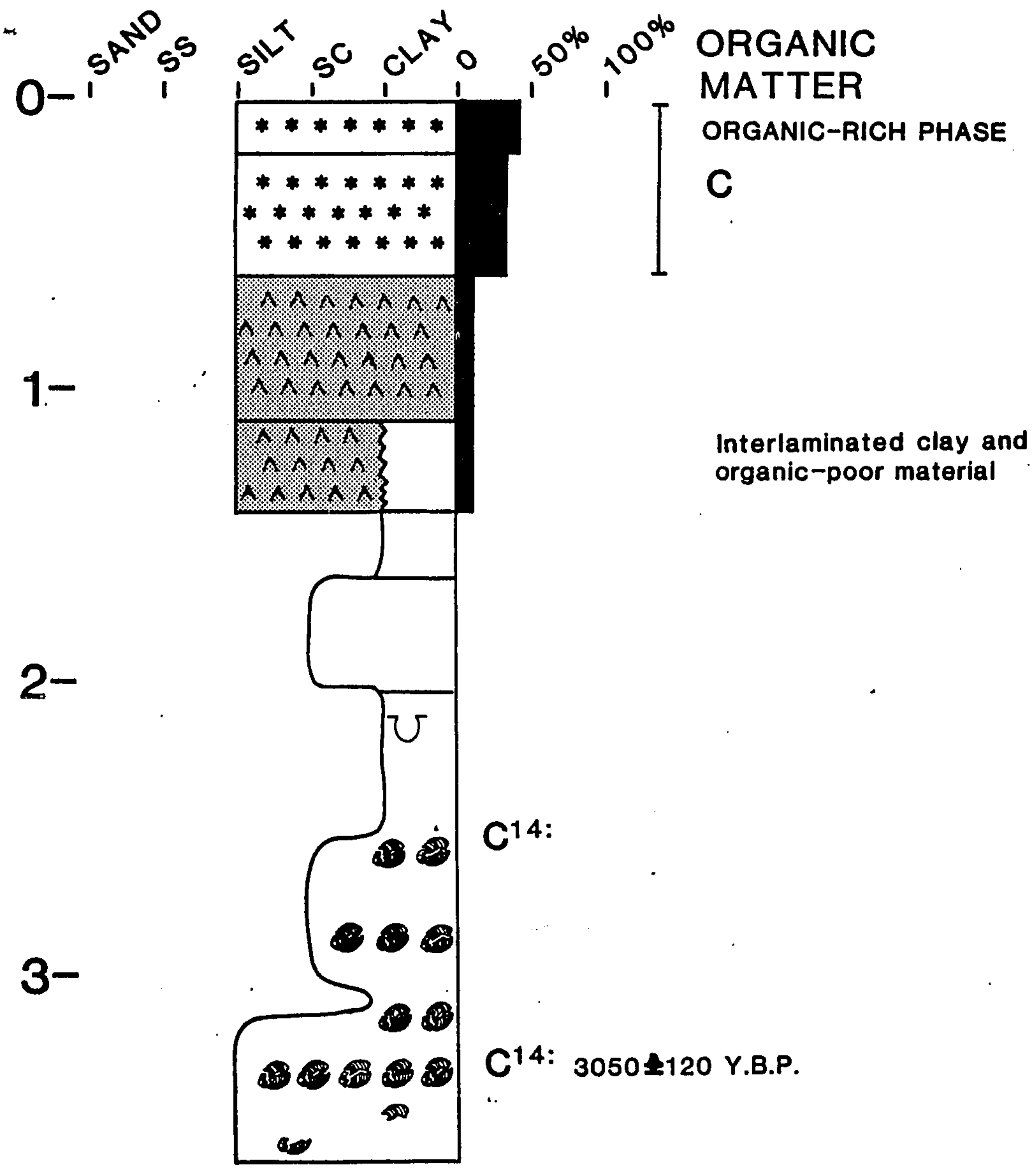
VIBRACORE BB53/106CM COMPACTION



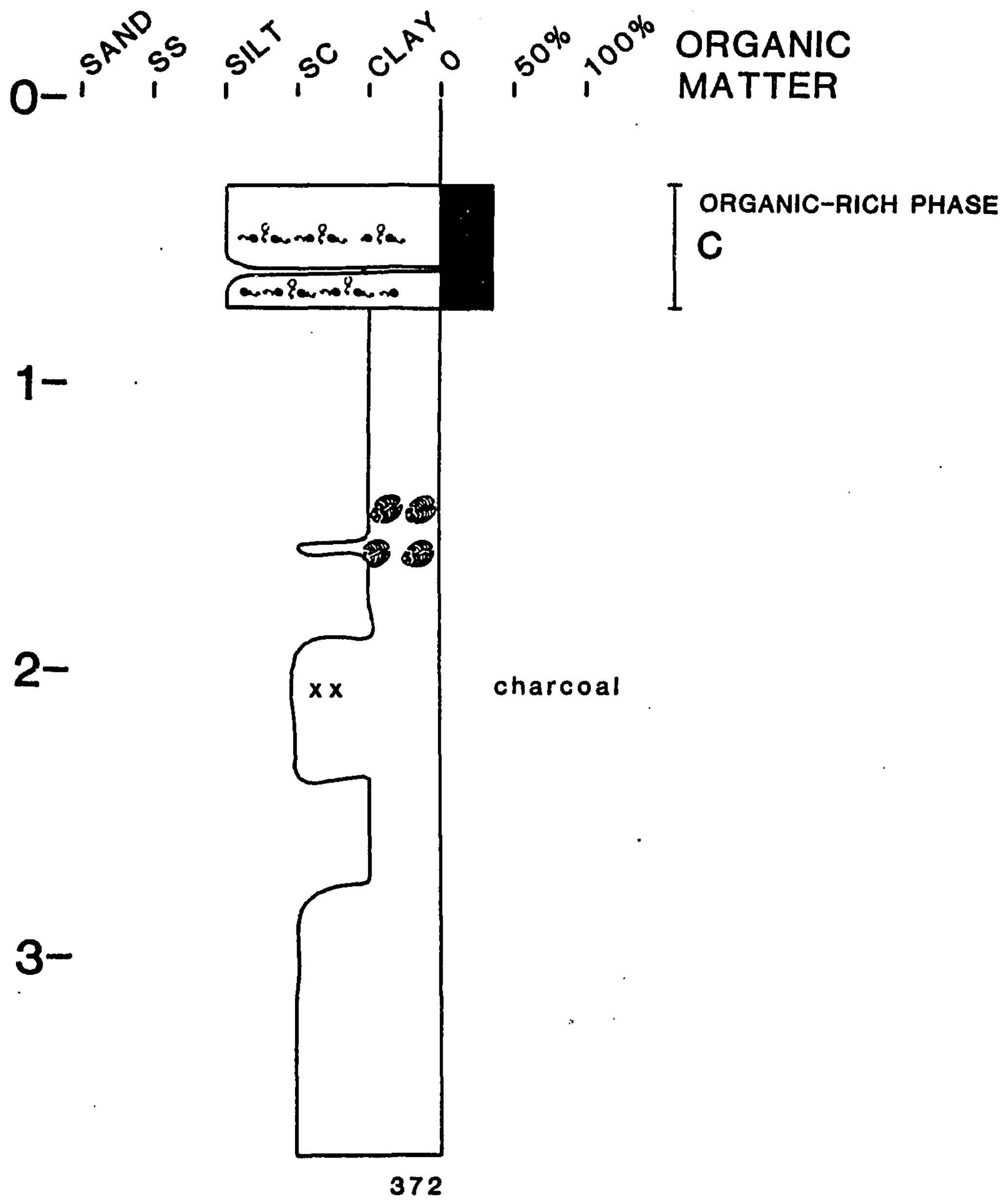
VIBRACORE BB54/112CM COMPACTION



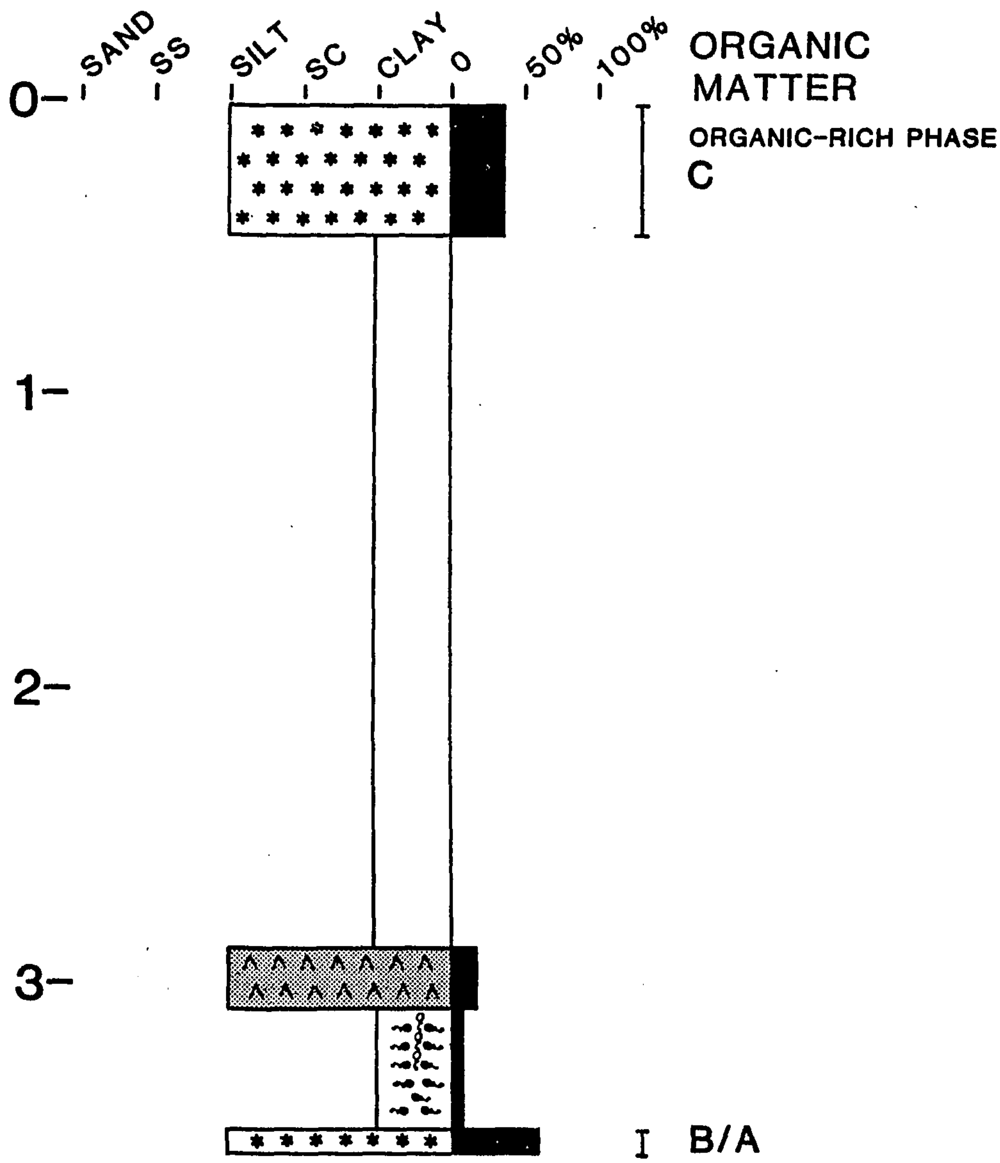
VIBRACORE BB55 / 40CM COMPACTION



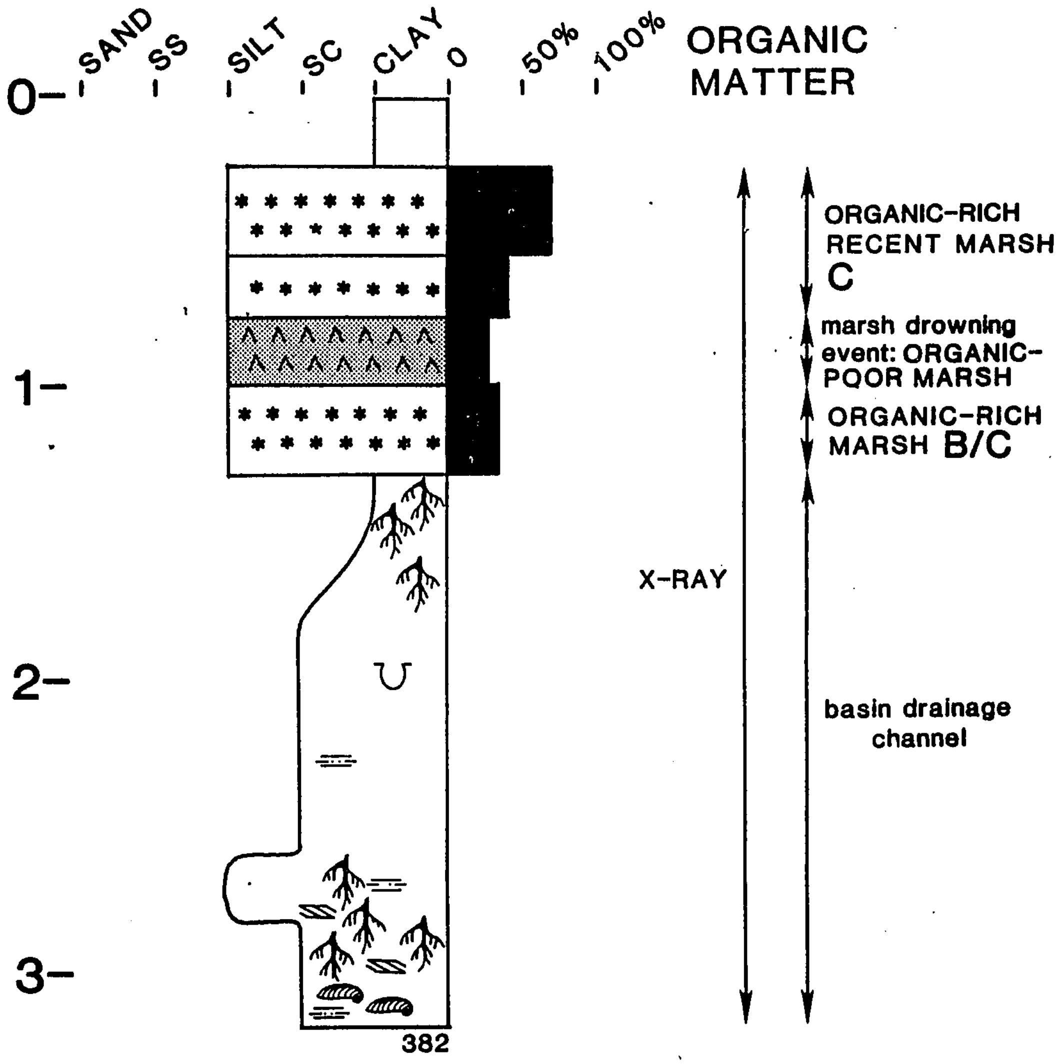
VIBRACORE BB56 / 28CM COMPACTION



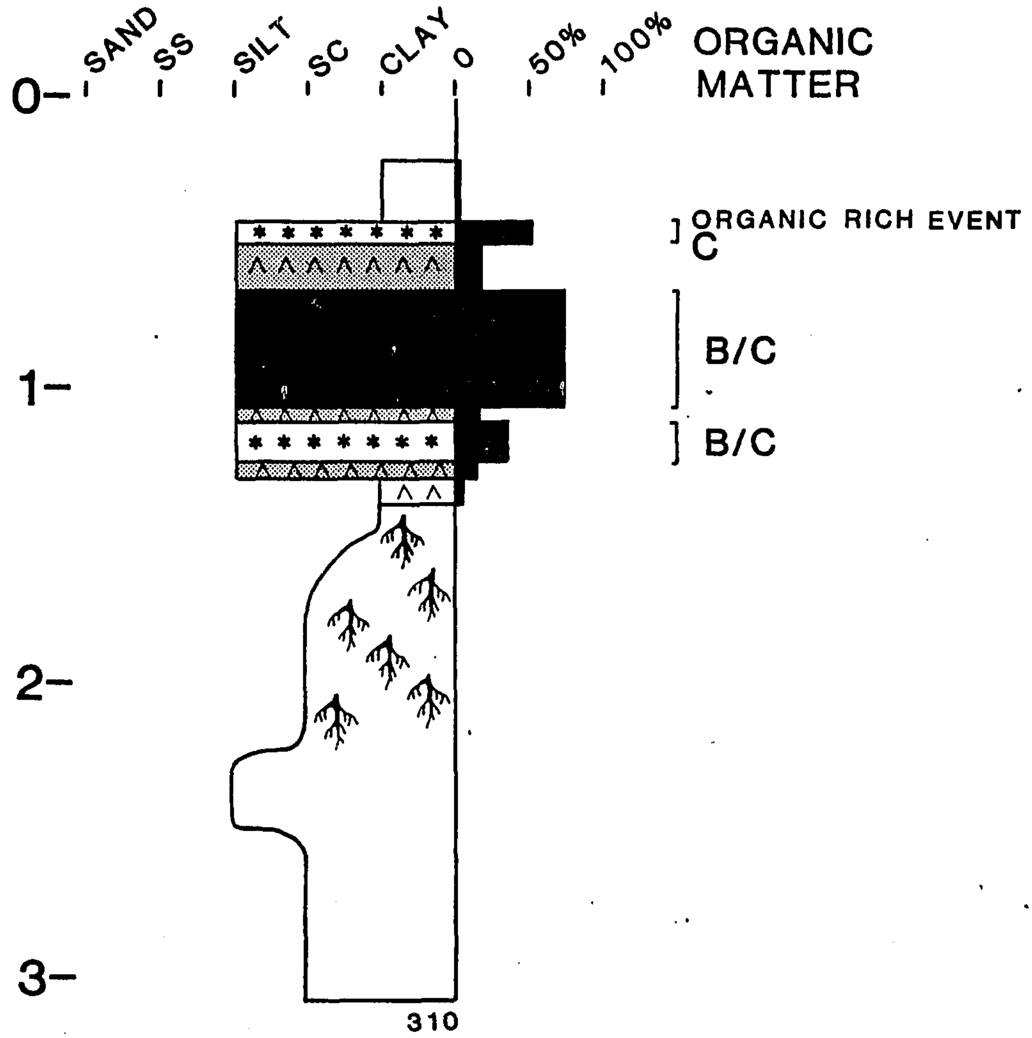
VIBRACORE BB57 / 68CM COMPACTION



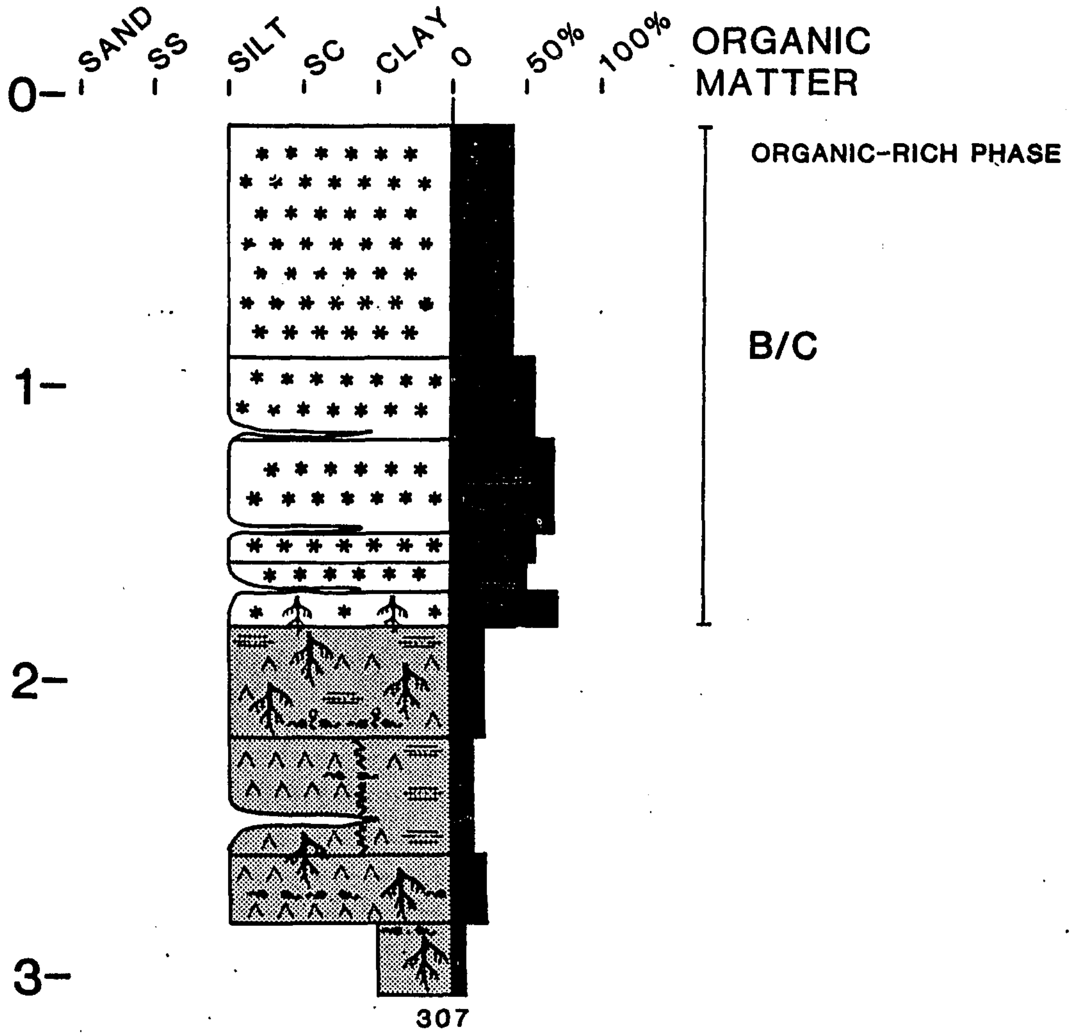
VIBRACORE BB58 / 70CM COMPACTION



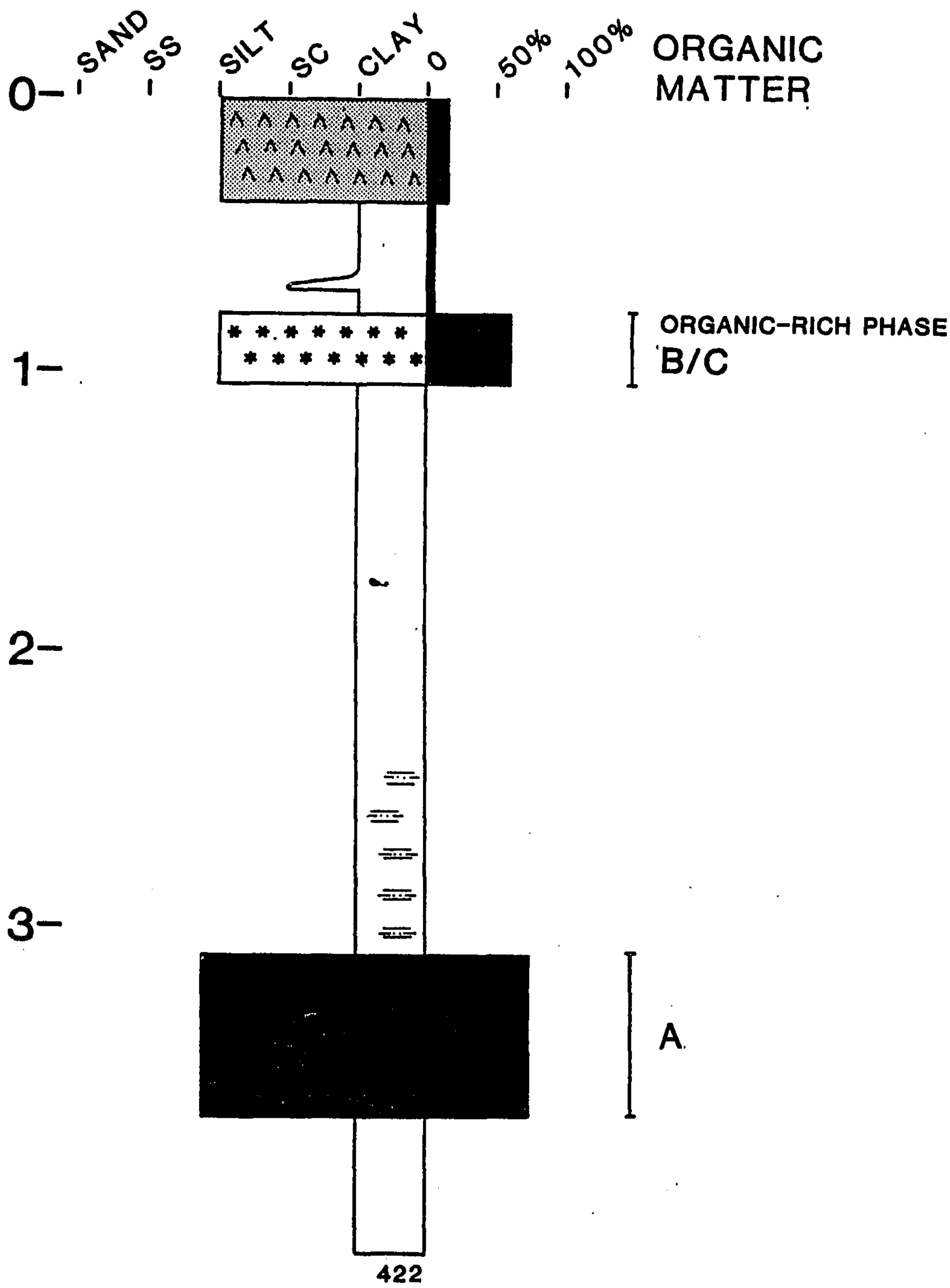
VIBRACORE BB59 / 84CM COMPACTION



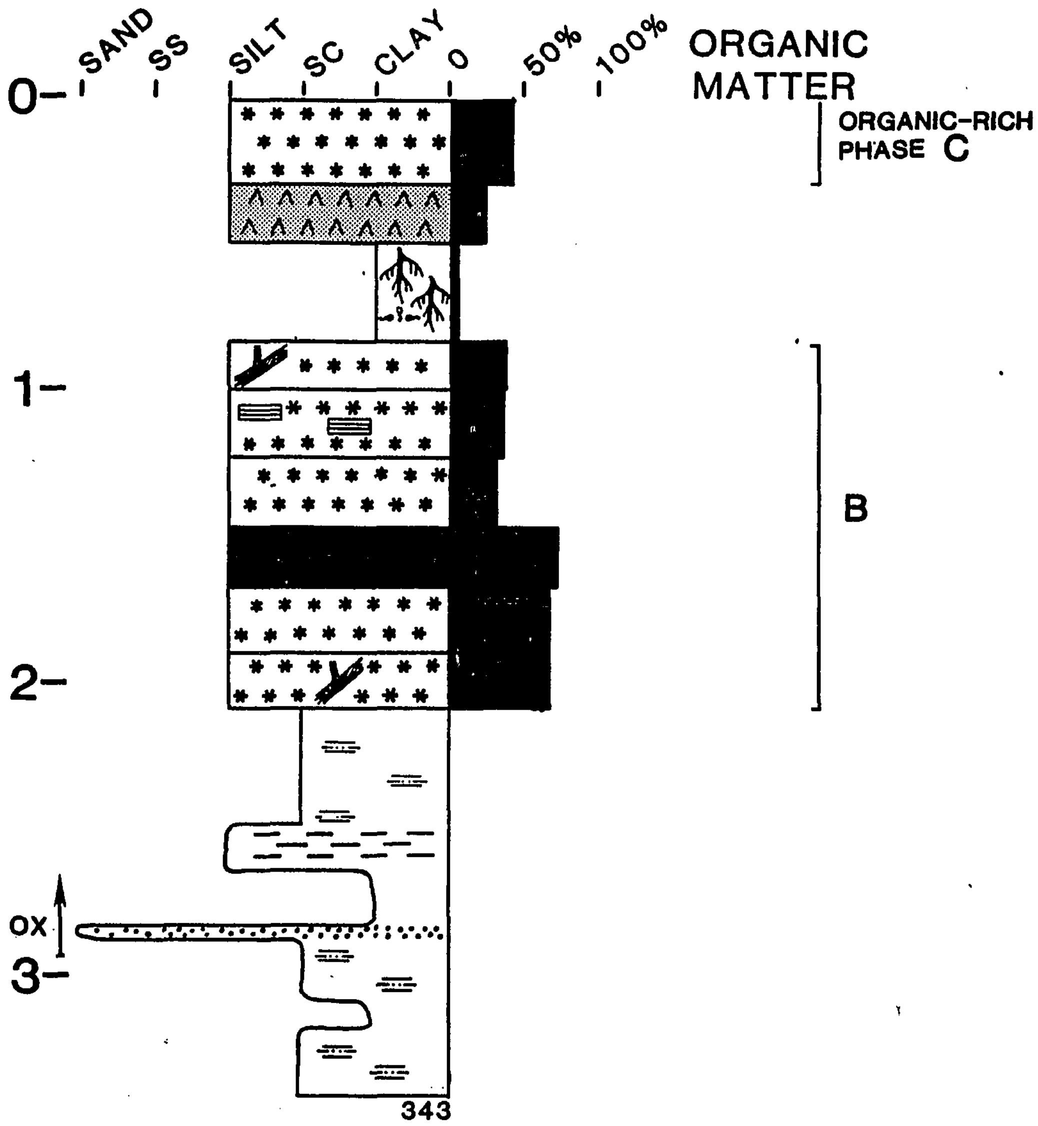
VIBRACORE BB60 / 76CM COMPACTION



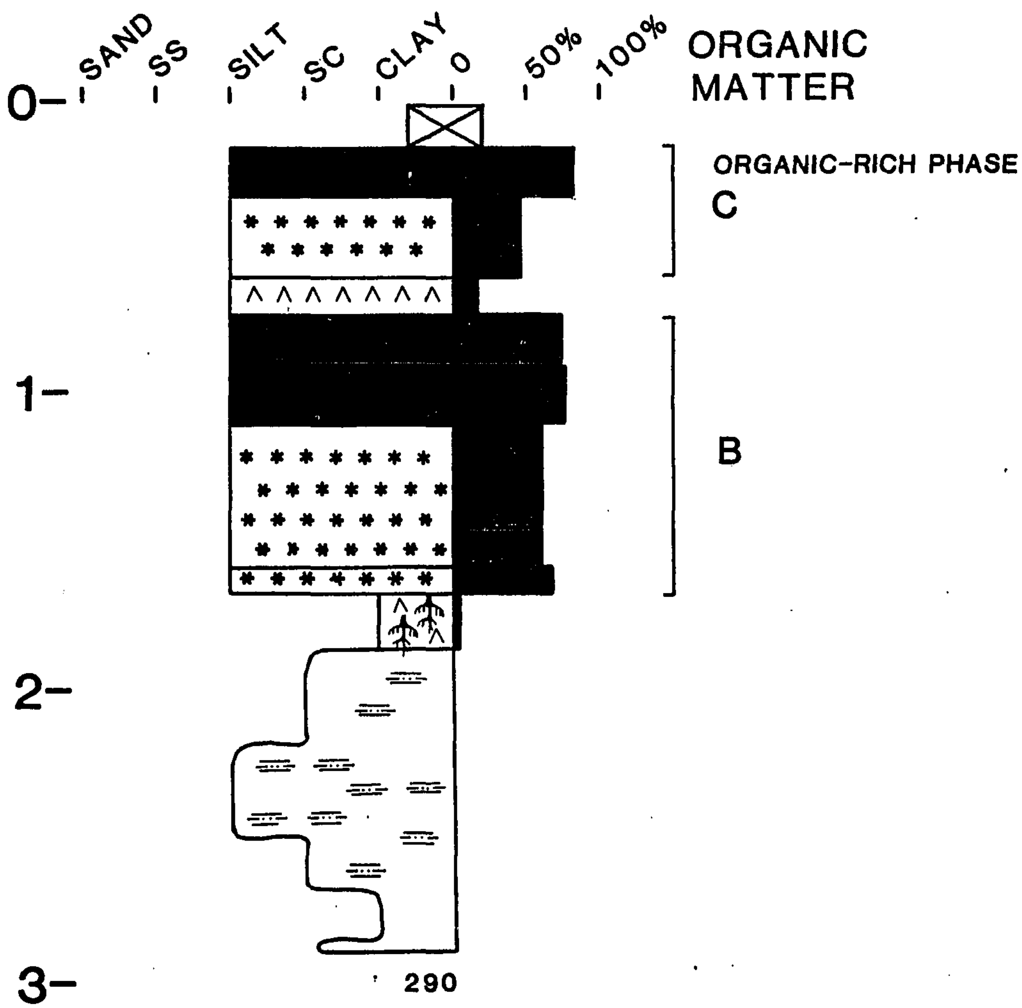
VIBRACORE BB61 / 66CM COMPACTION



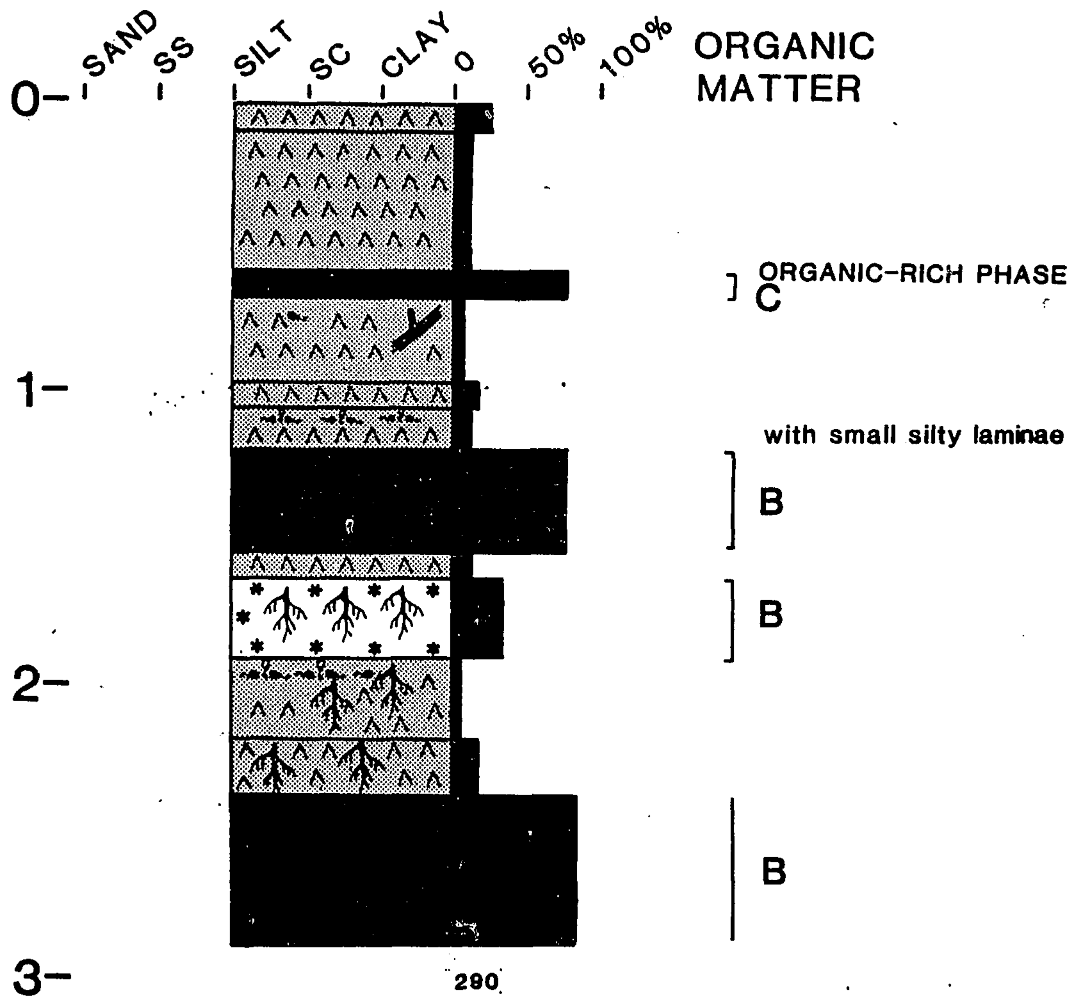
VIBRACORE BB 62 / 61 CM COMPACTION



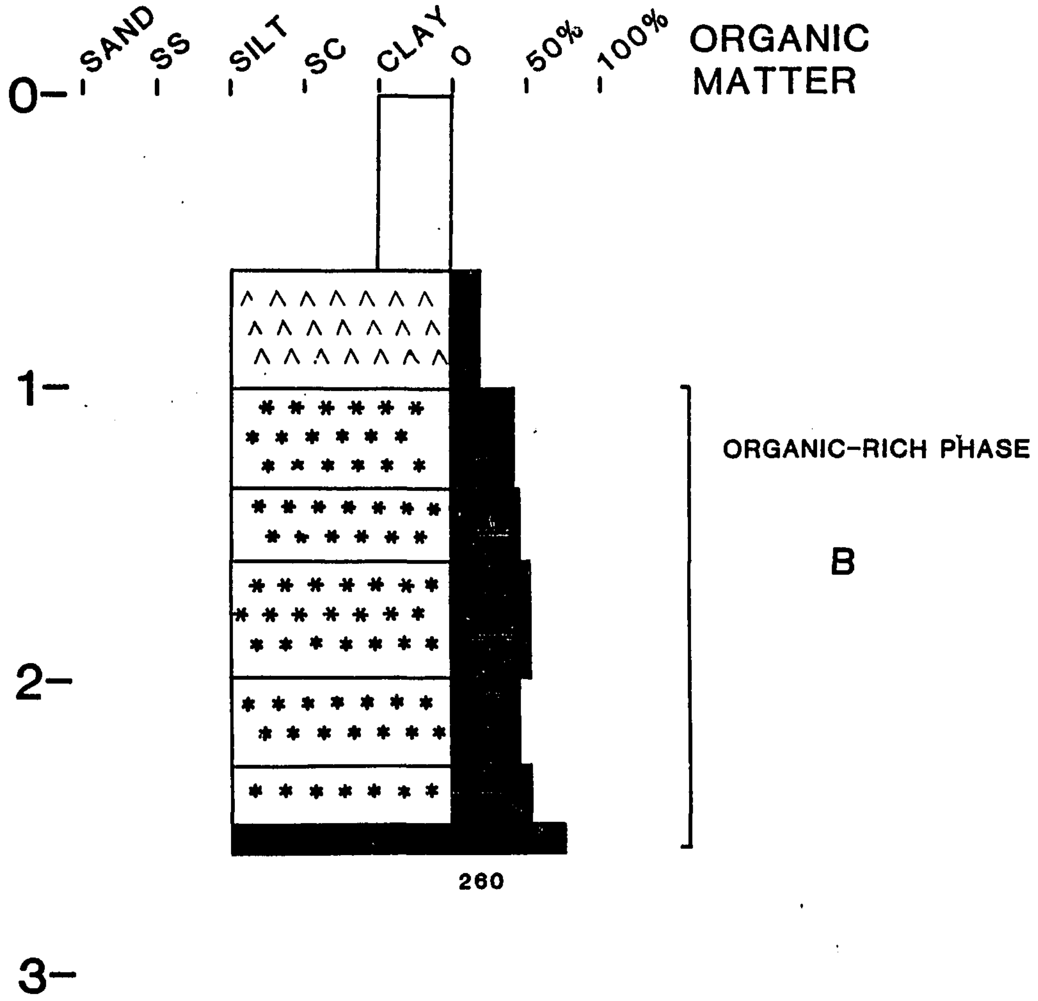
VIBRACORE BB63 / 61CM COMPACTION



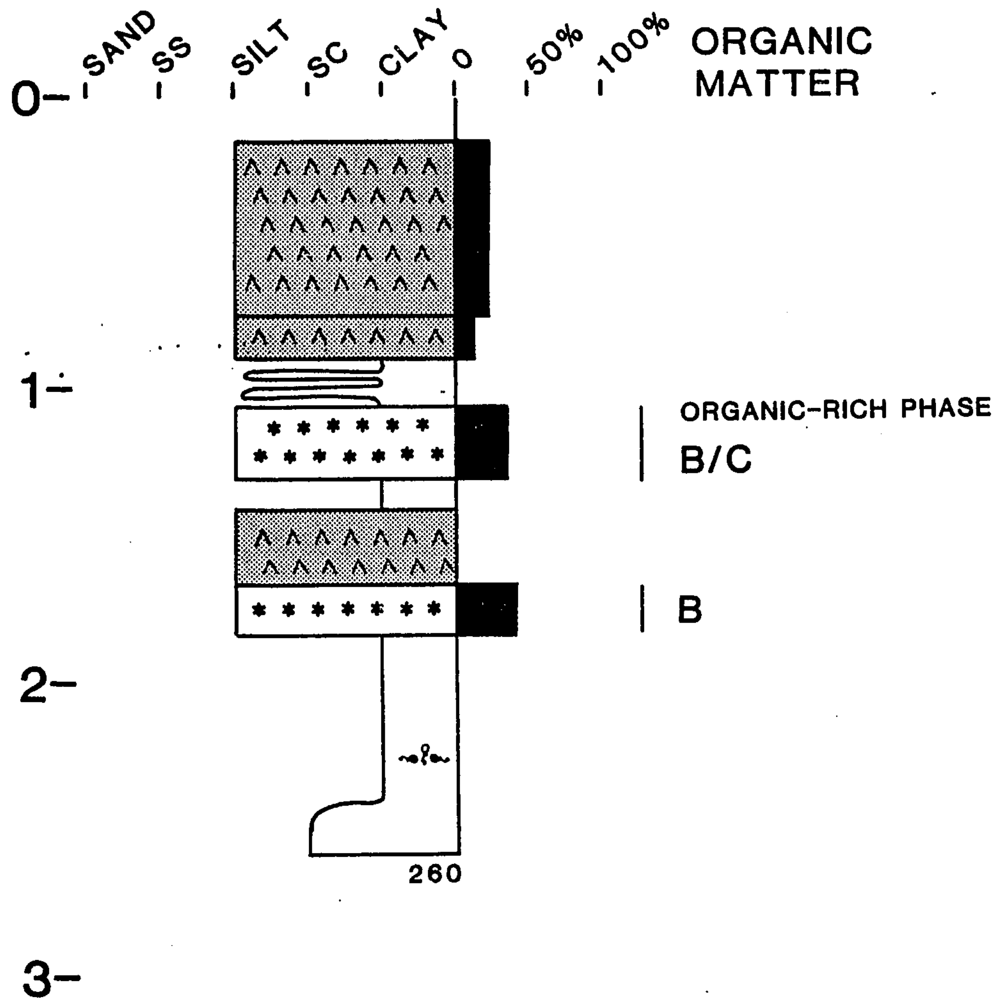
VIBRACORE BB64 / 36CM COMPACTION



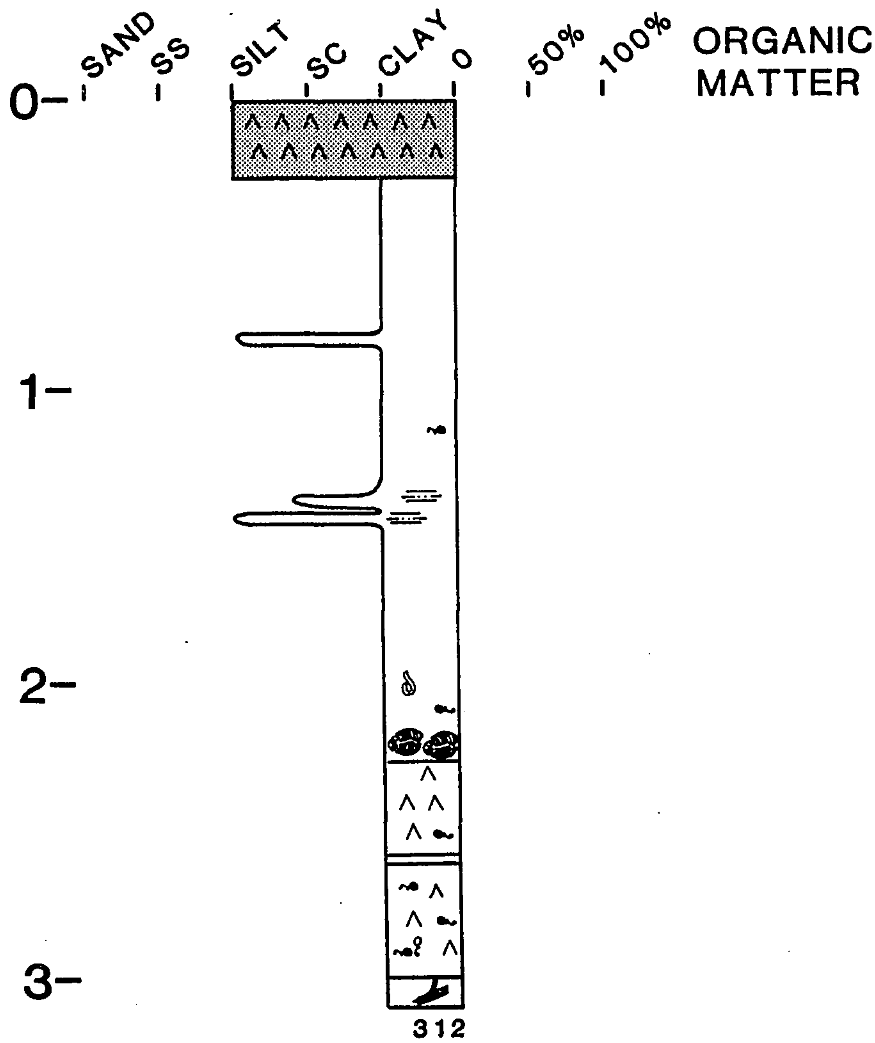
VIBRACORE BB65 / ?CM COMPACTION



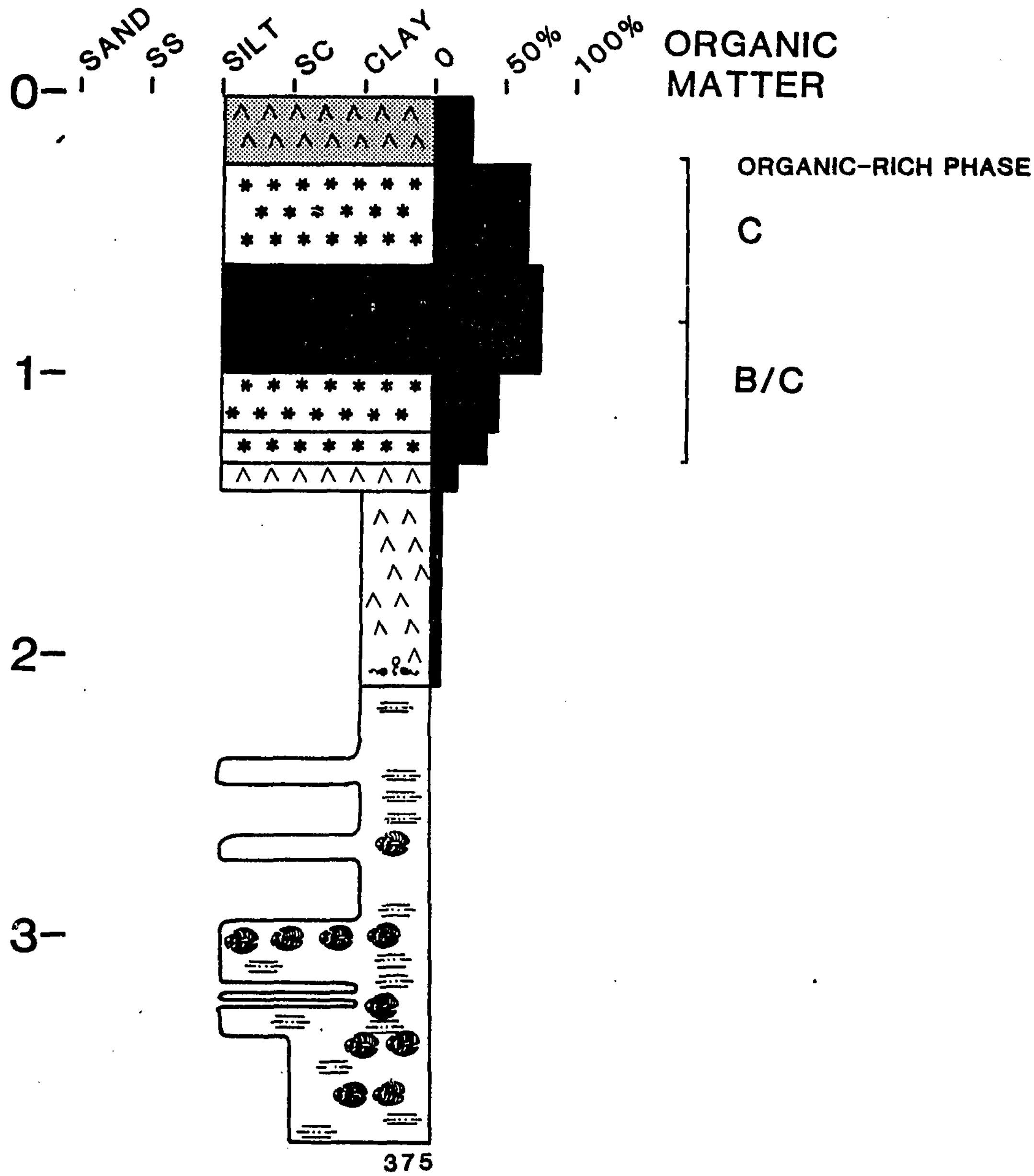
VIBRACORE BB66 150 CM COMPACTION



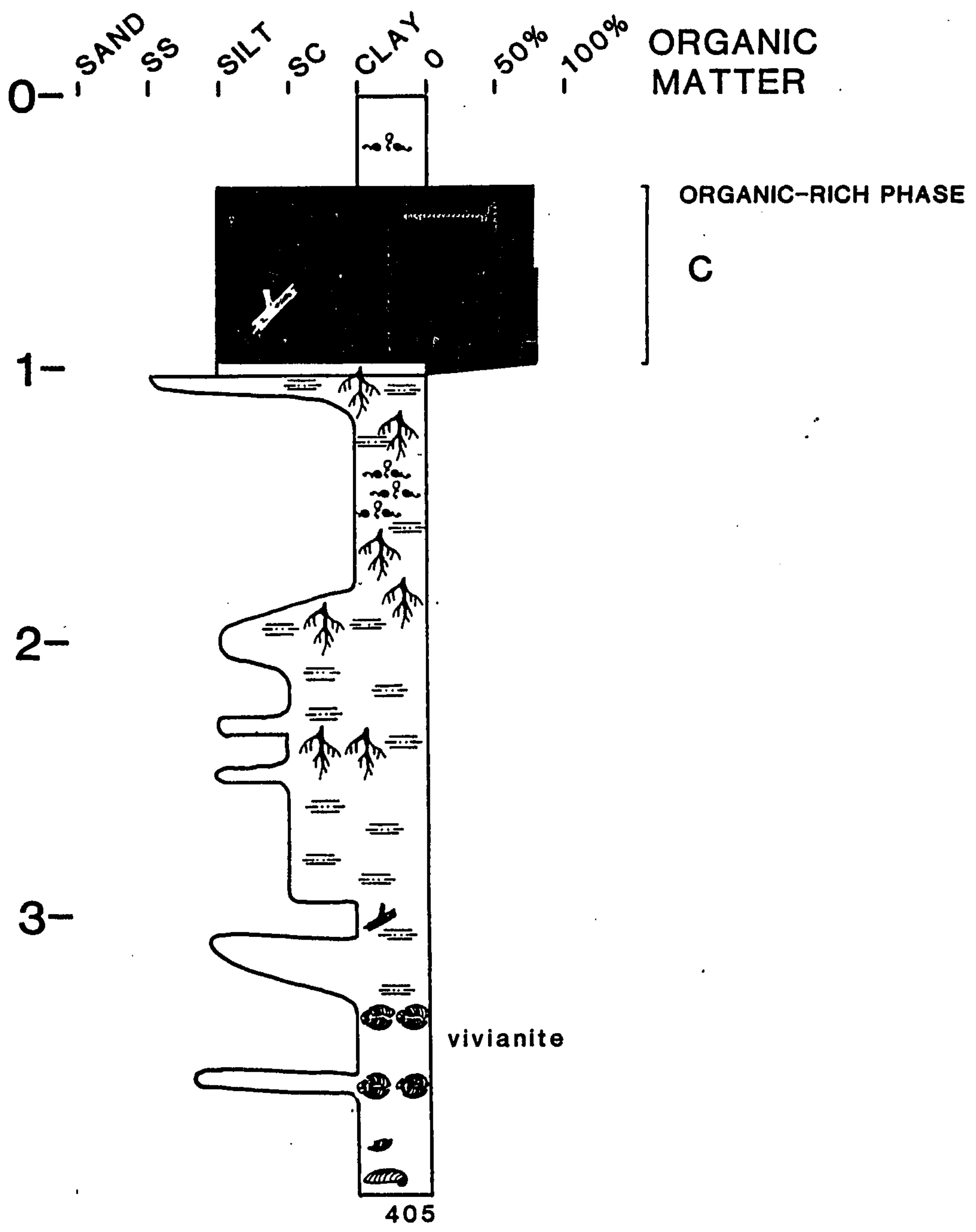
VIBRACORE BB67/100CM COMPACTION



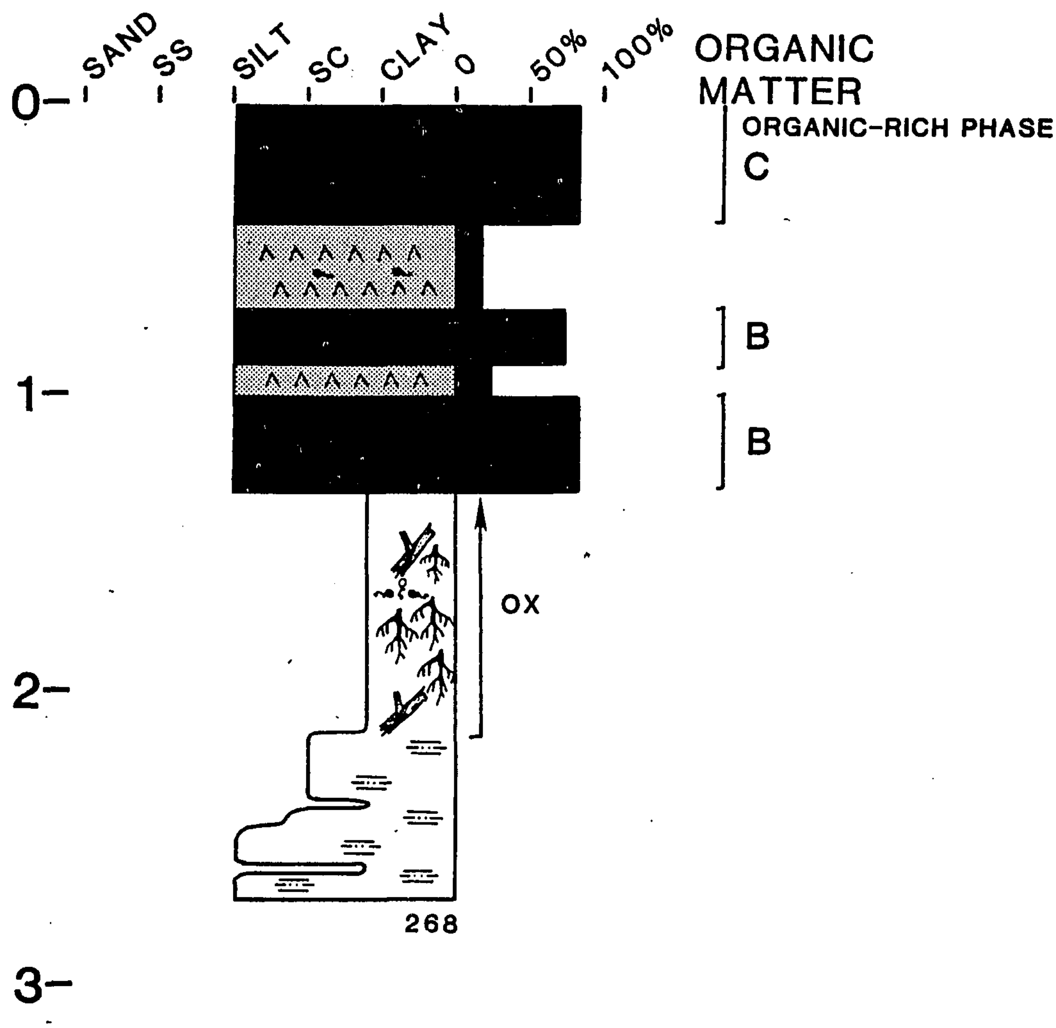
VIBRACORE BB68 / 31CM COMPACTION



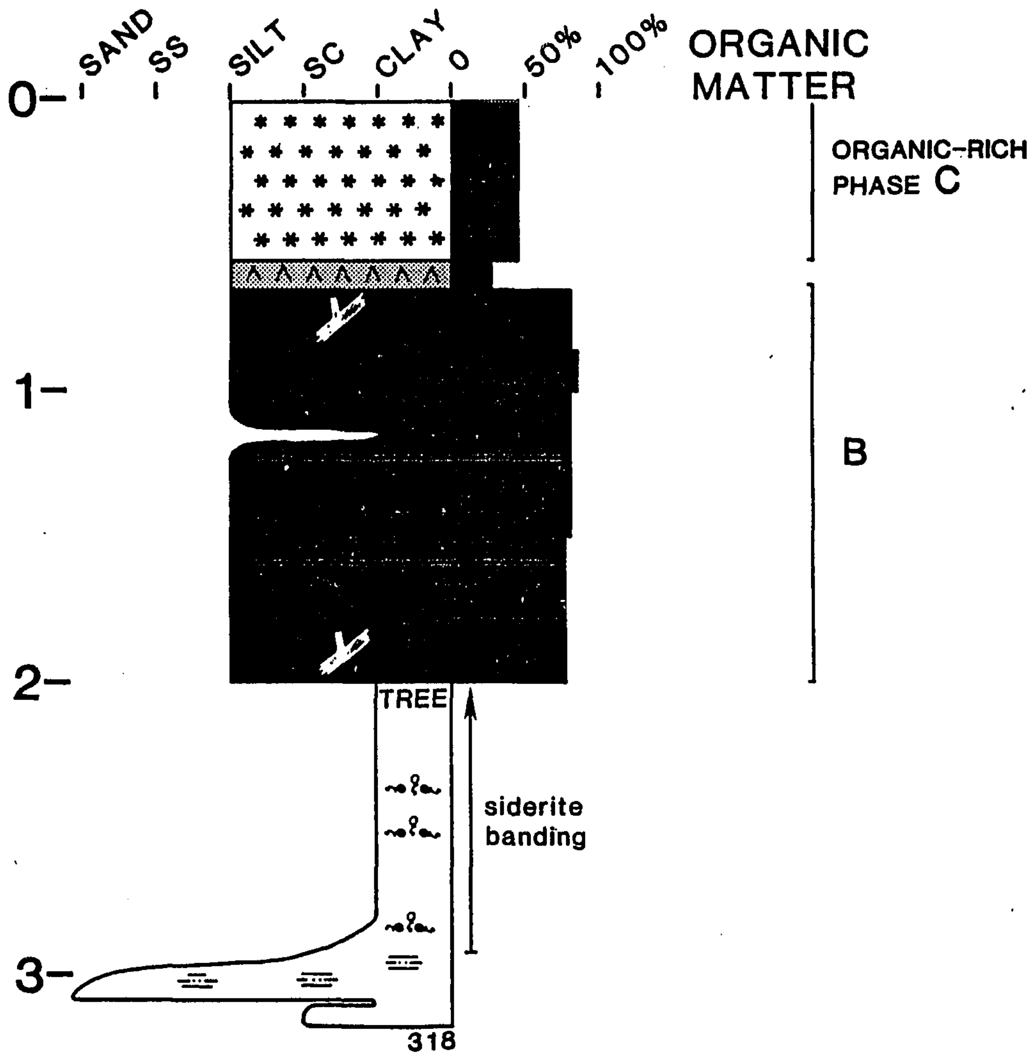
VIBRACORE BB69 / 15CM COMPACTION



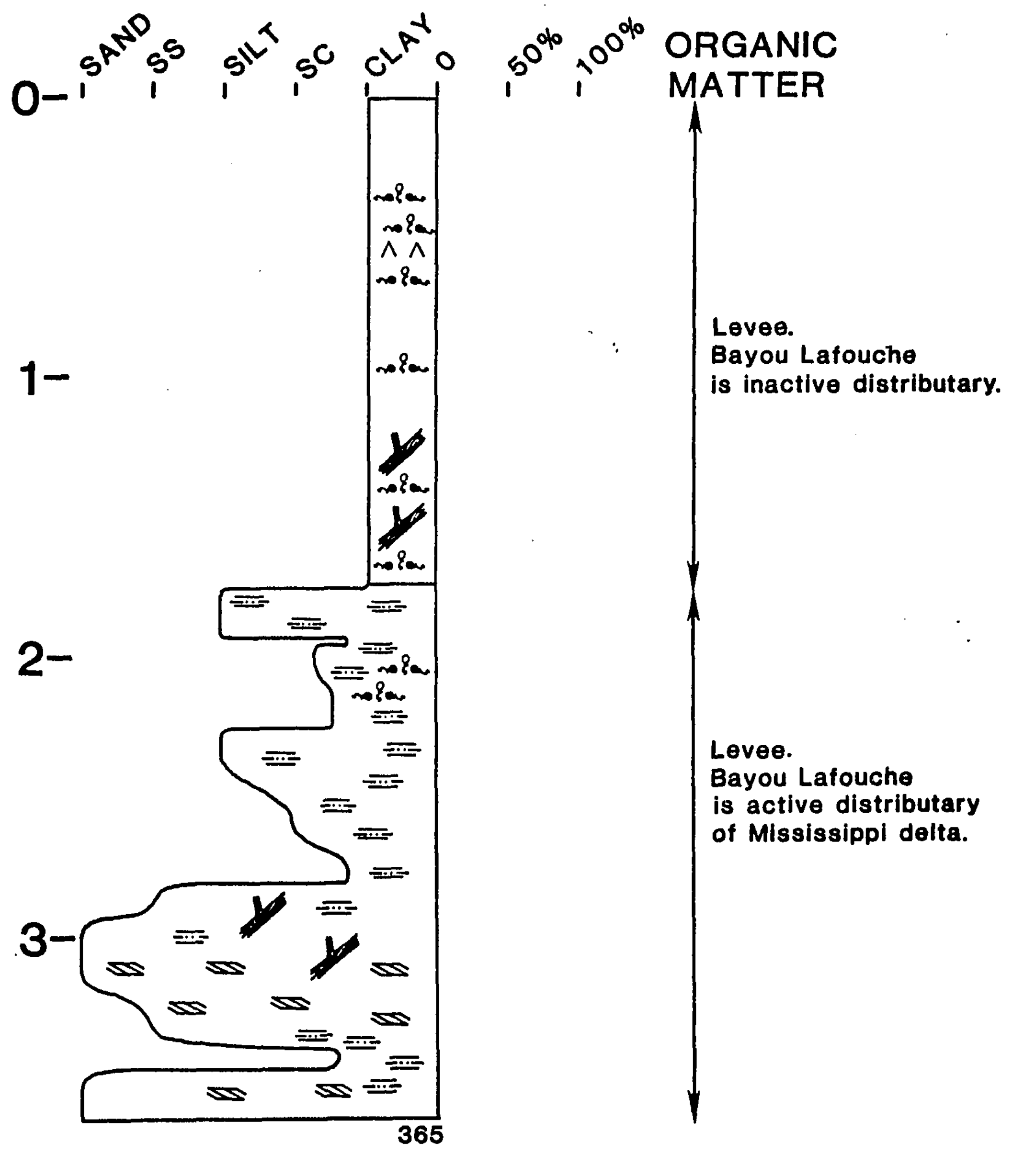
VIBRACORE BB70/153CM COMPACTION

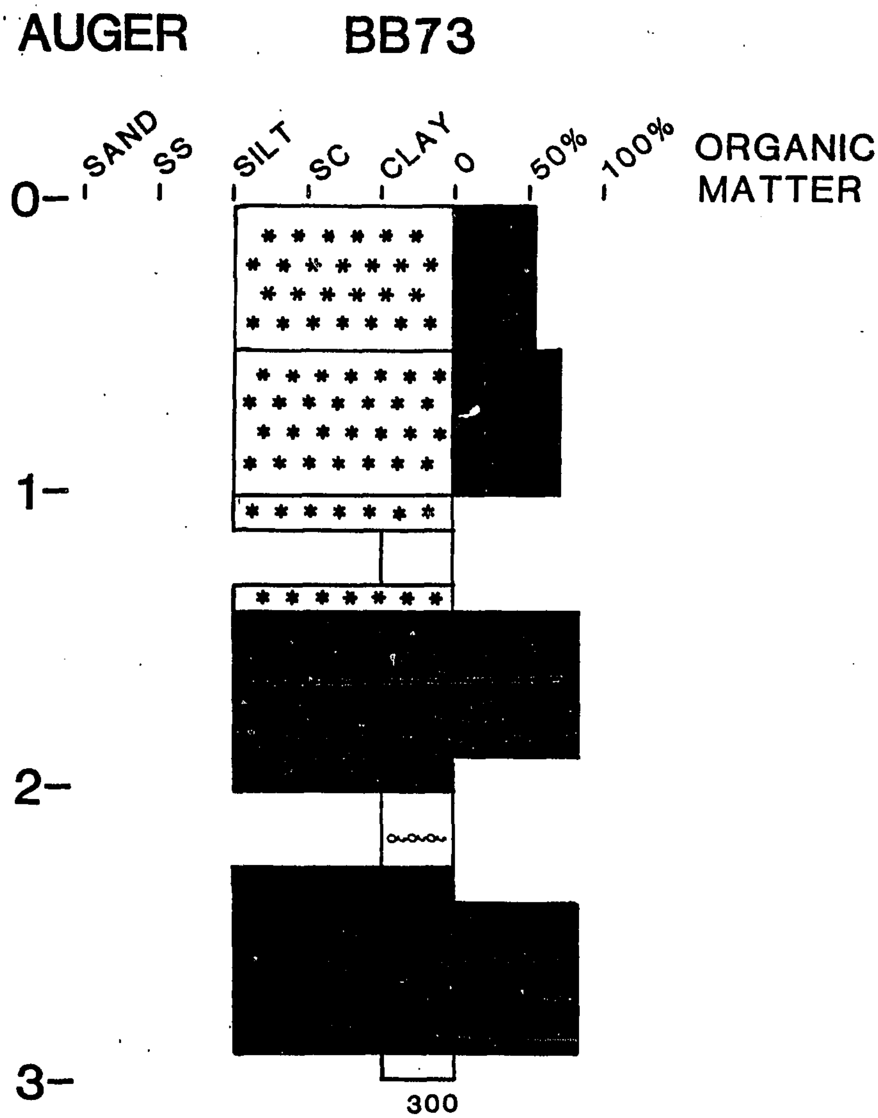


VIBRACORE BB71 / 80CM COMPACTION

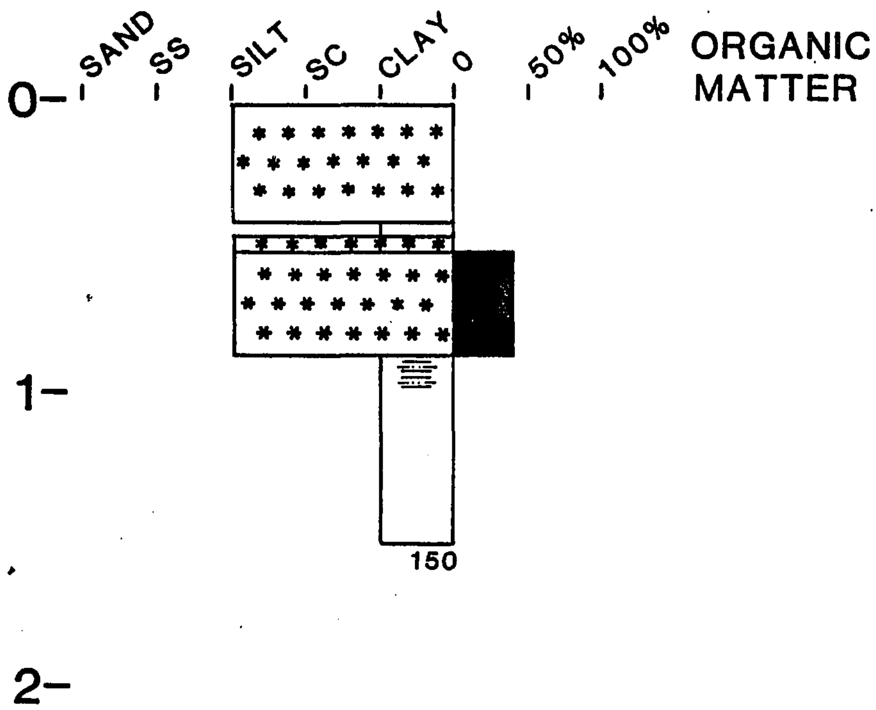


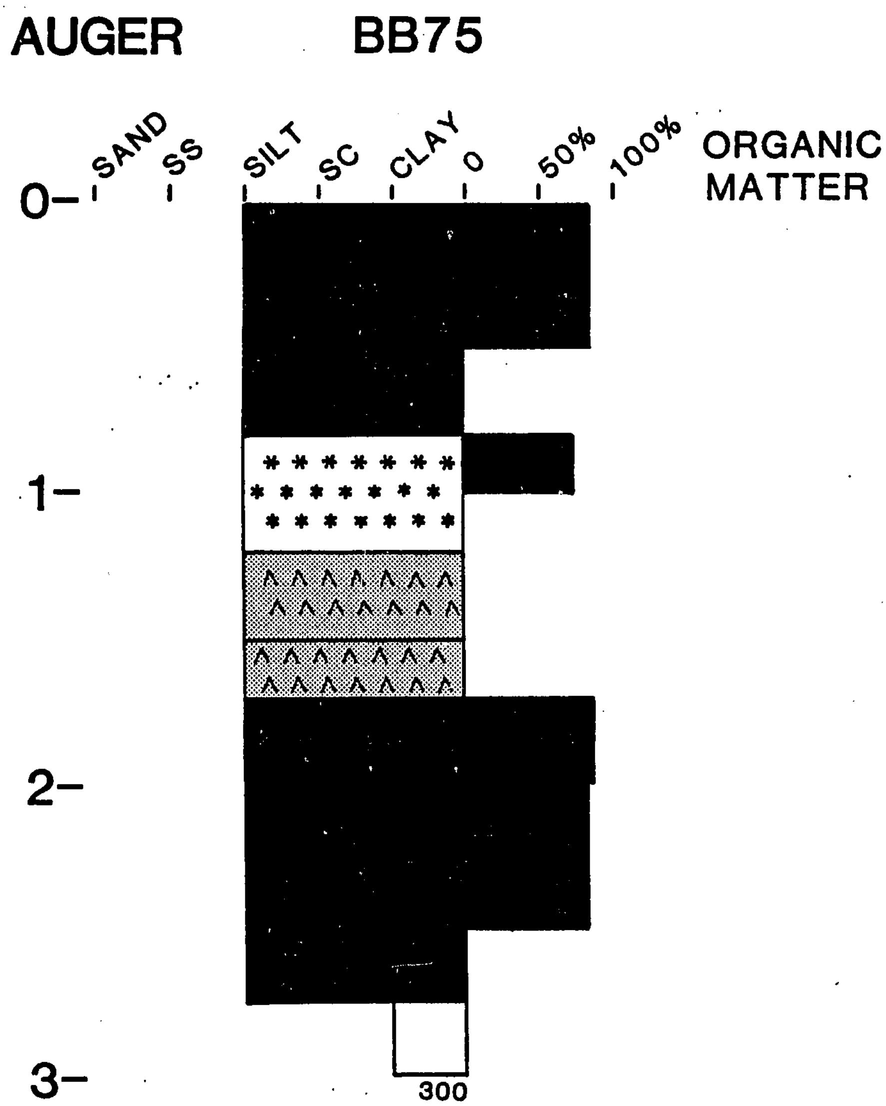
VIBRACORE BB 72 / 0 CM COMPACTION

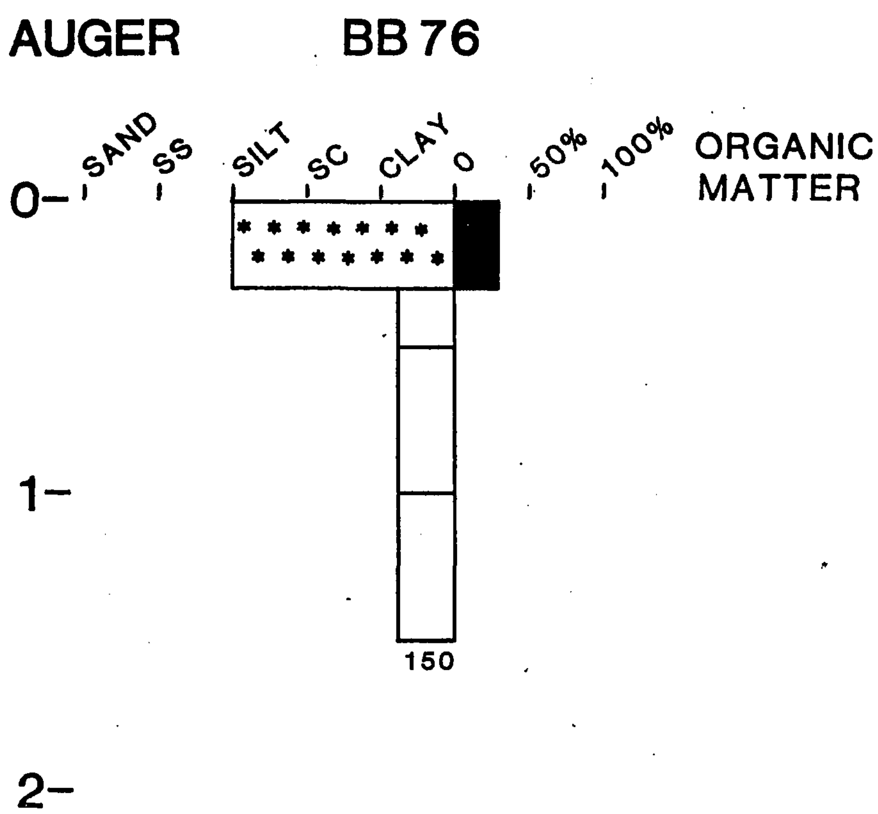


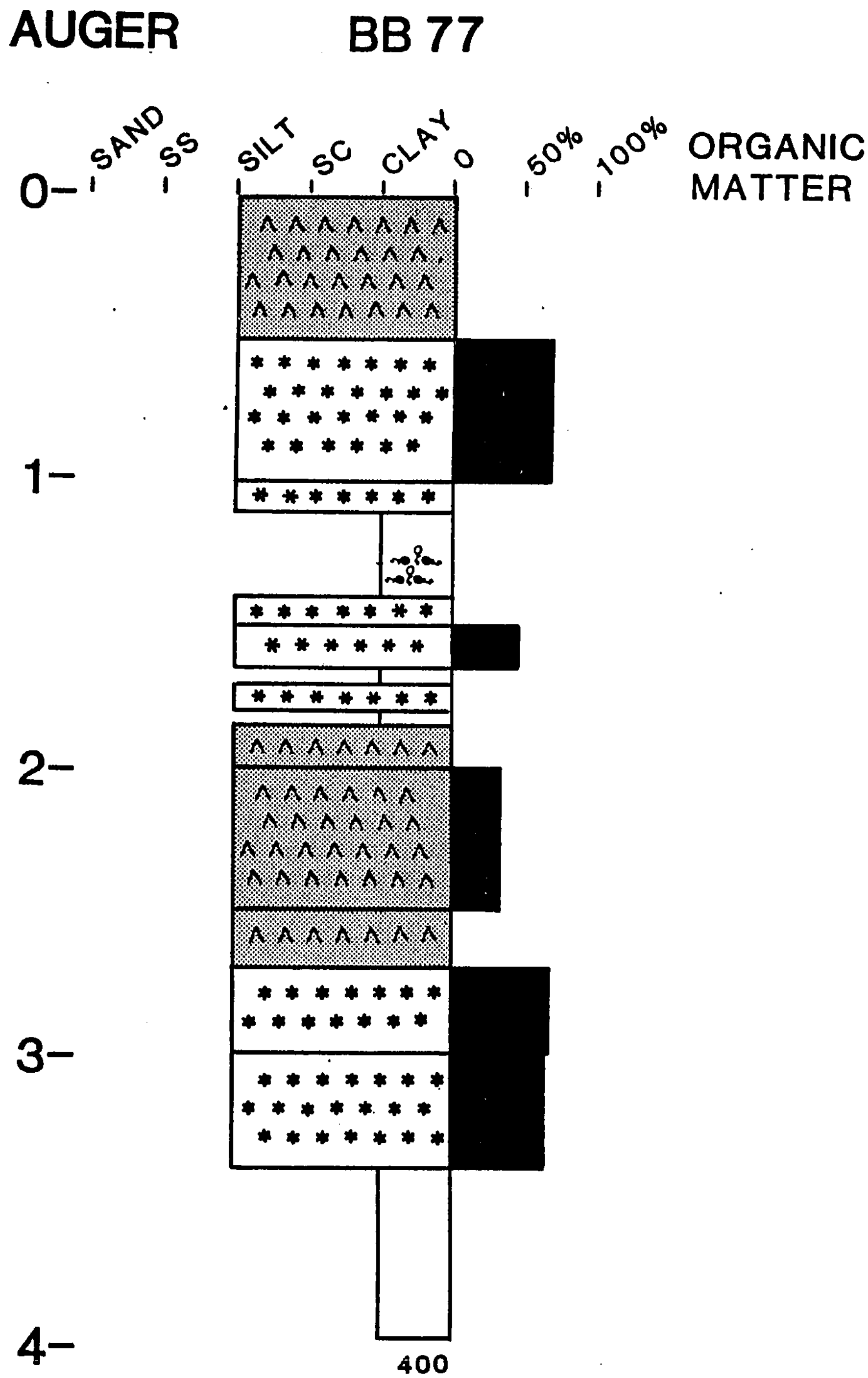

AUGER BB73
SAND
SS
SILT
SC
CLAY
0
50%
100%
ORGANIC MATTER
0–
1–
2–
3–
300

AUGER BB74



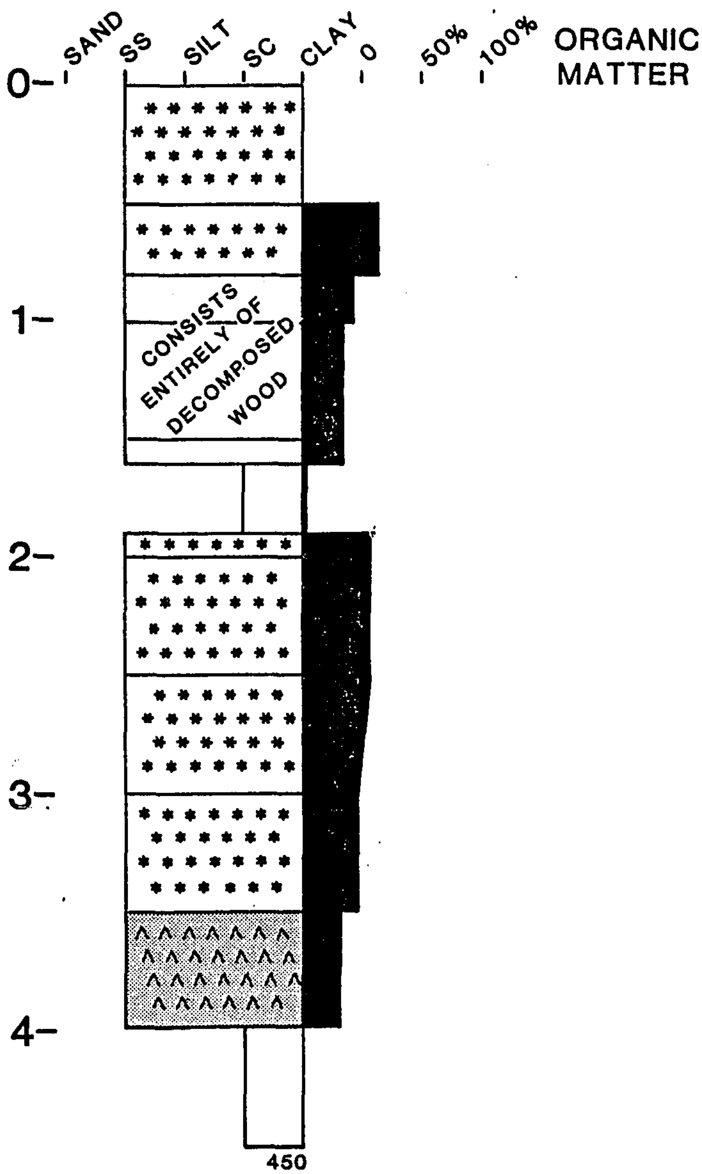

AUGER
BB75
SAND
SS
SILT
SC
CLAY
0
50%
100%
ORGANIC MATTER
0–
1–
2–
3–
300

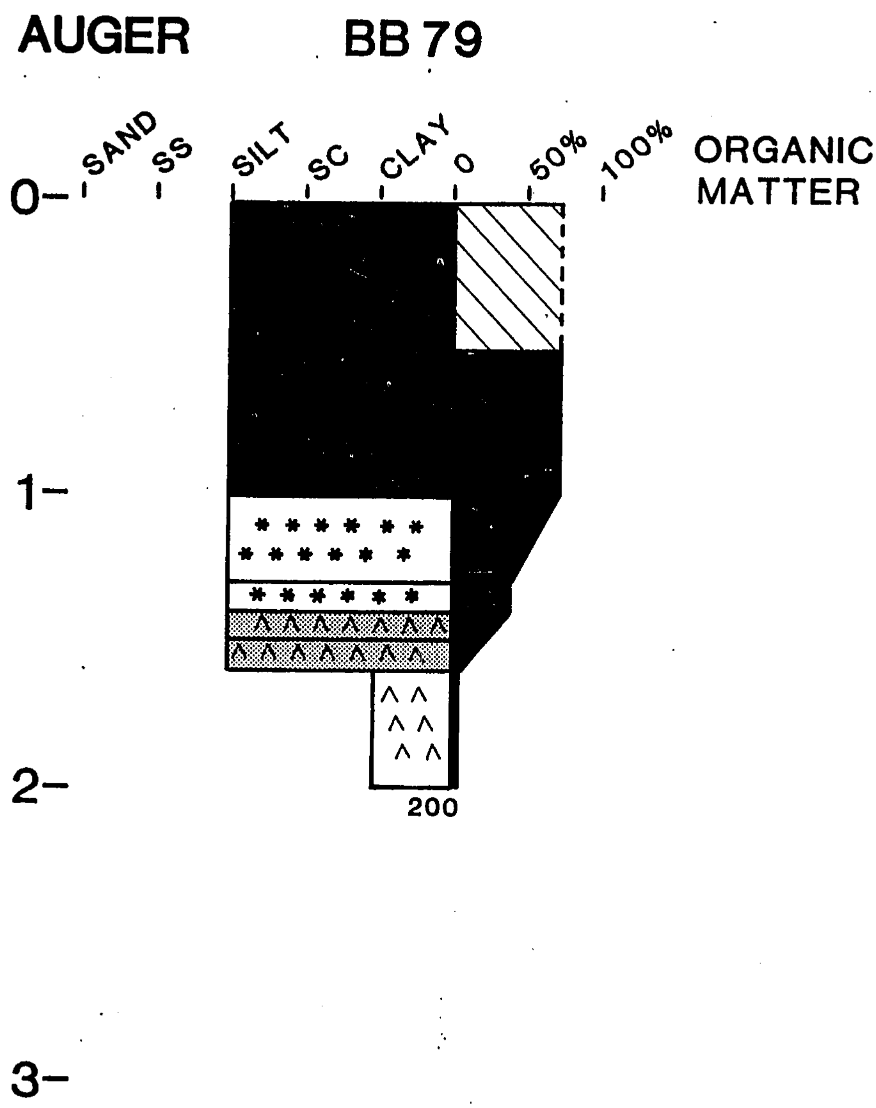

AUGER
BB 76
SAND
SS
SILT
SC
CLAY
O
50%
100%
ORGANIC MATTER
0–
1–
2–
150



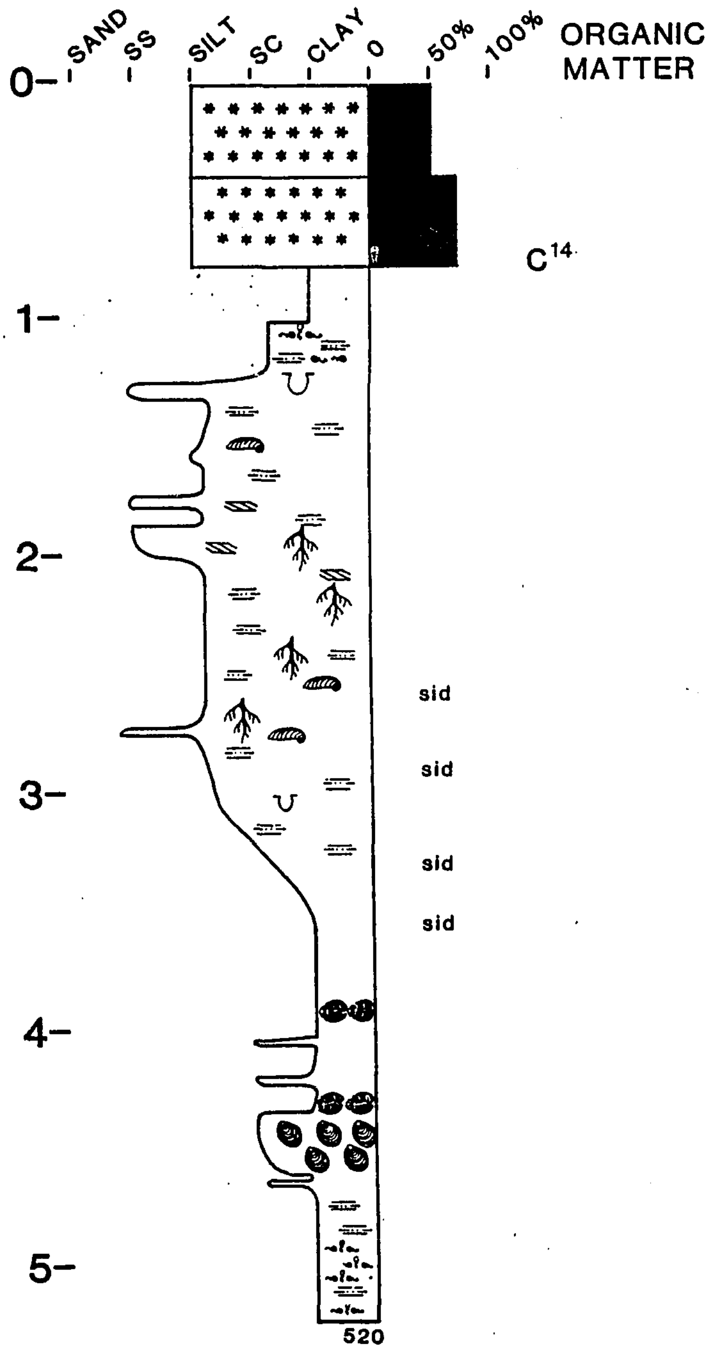
AUGER
BB 77
SAND
SS
SILT
SC
CLAY
0
50%
100%
ORGANIC MATTER
0–
1–
2–
3–
4–
400

AUGER BB 78

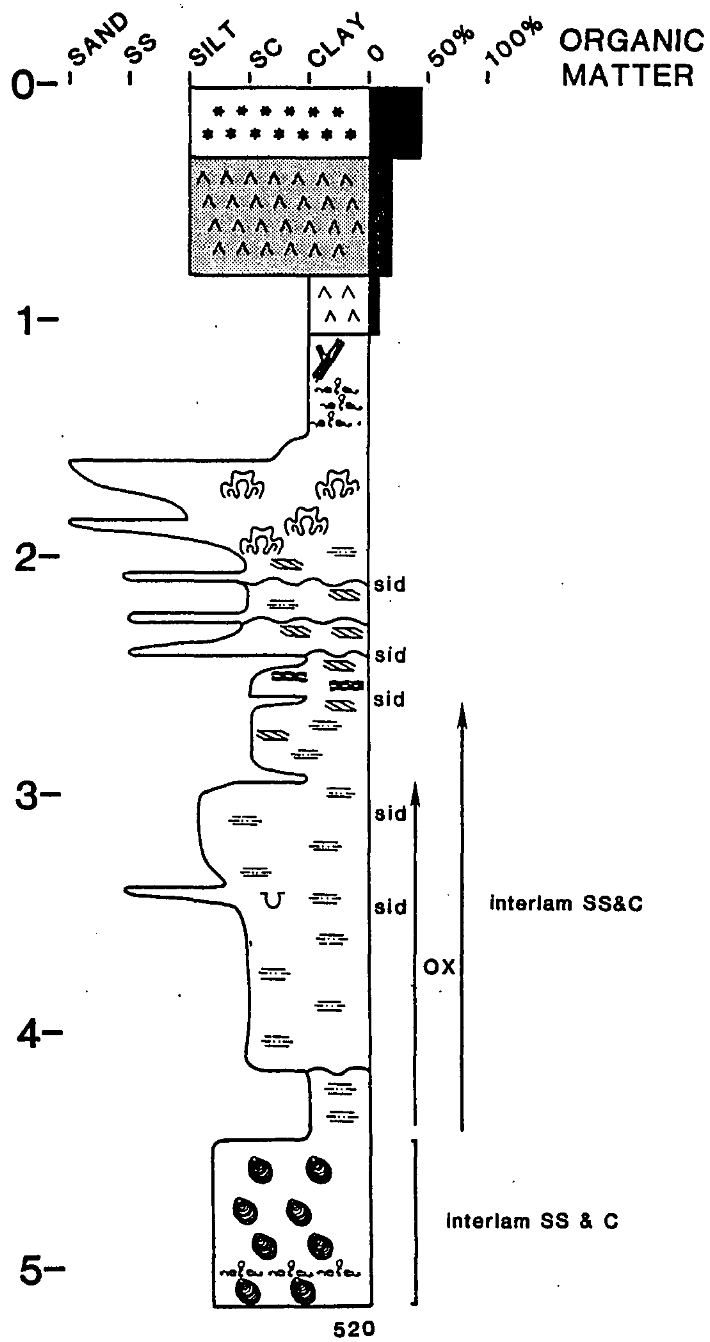

SAND
SS
SILT
SC
CLAY
0
50%
100%
ORGANIC MATTER
0
1
2
3
4
CONSISTS ENTIRELY OF DECOMPOSED WOOD
450


AUGER
BB 79
0–
1–
2–
3–
SAND
SS
SILT
SC
CLAY
0
50%
100%
ORGANIC MATTER
200

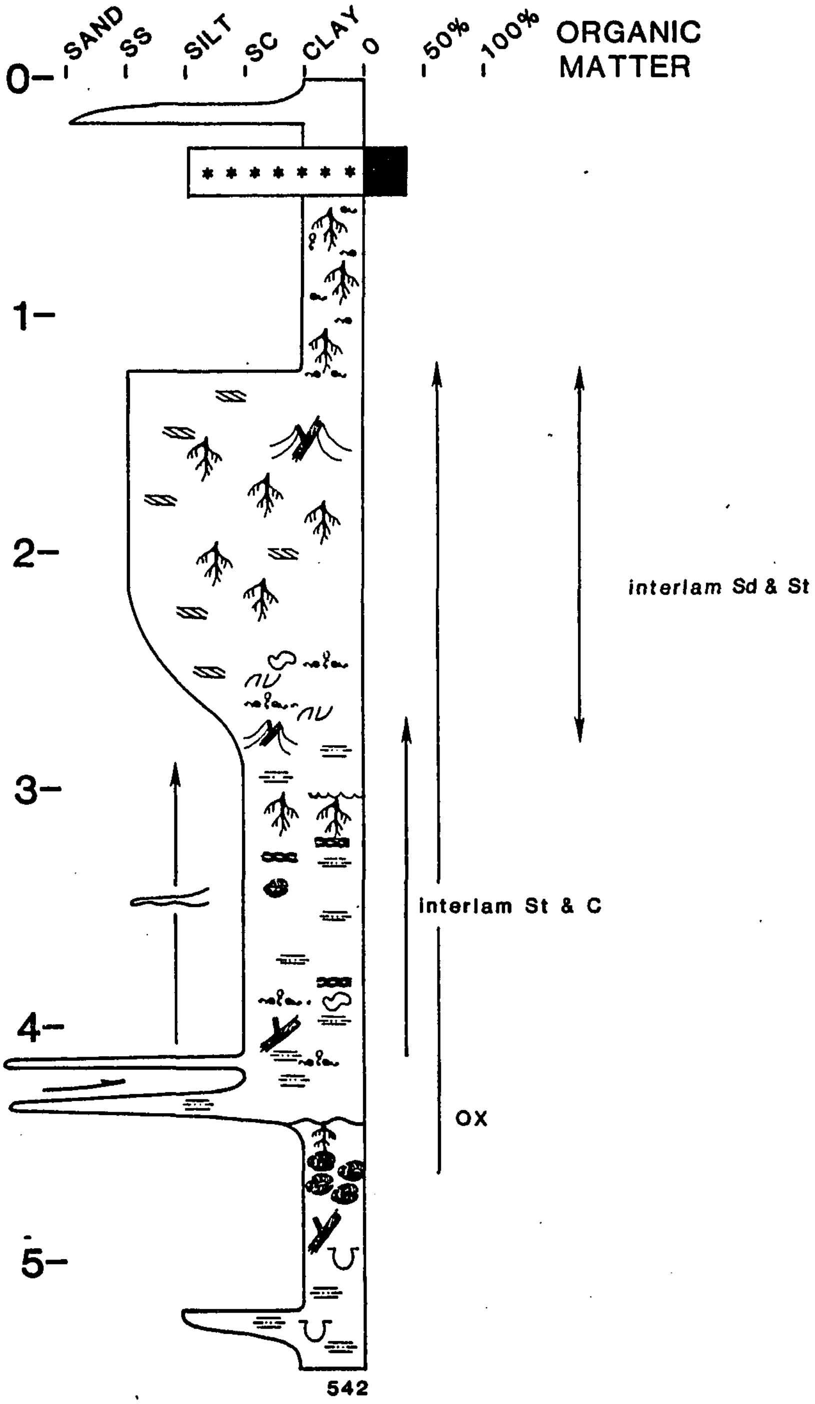
VIBRACORE BB80 / 25CM COMPACTION



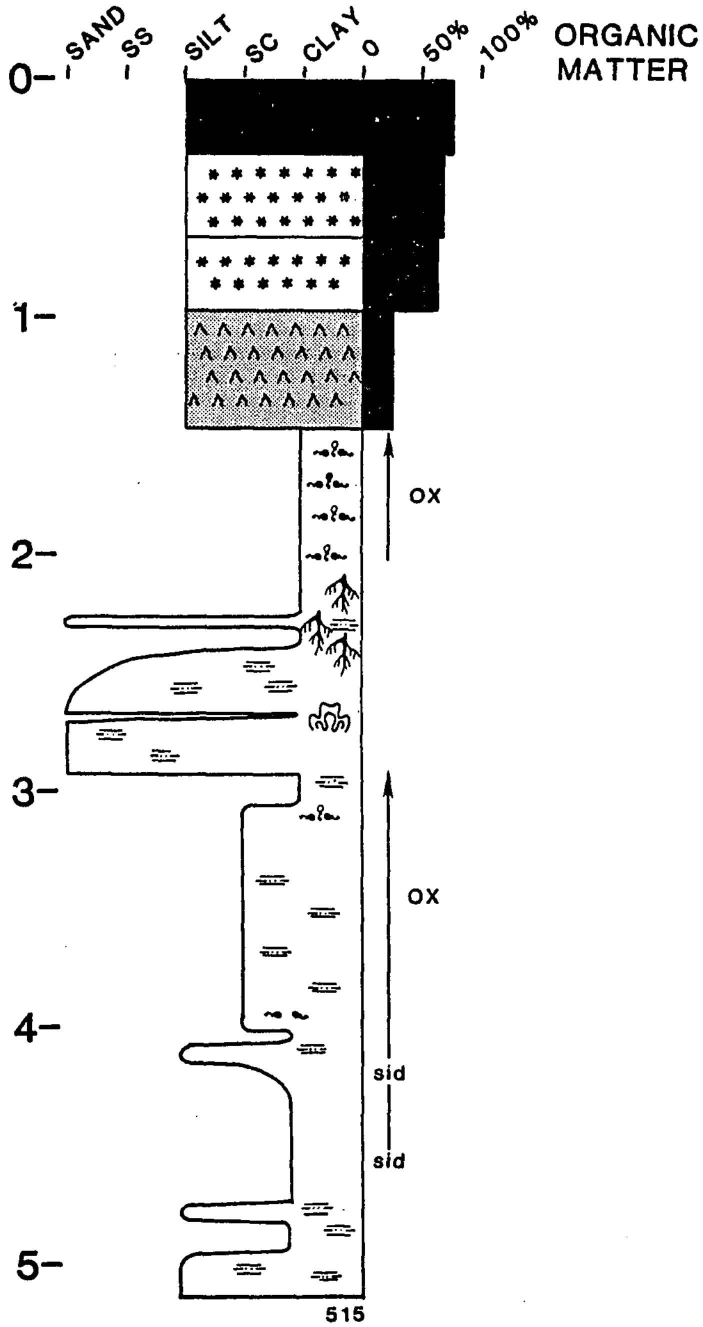
VIBRACORE BB81 / 25CM COMPACTION

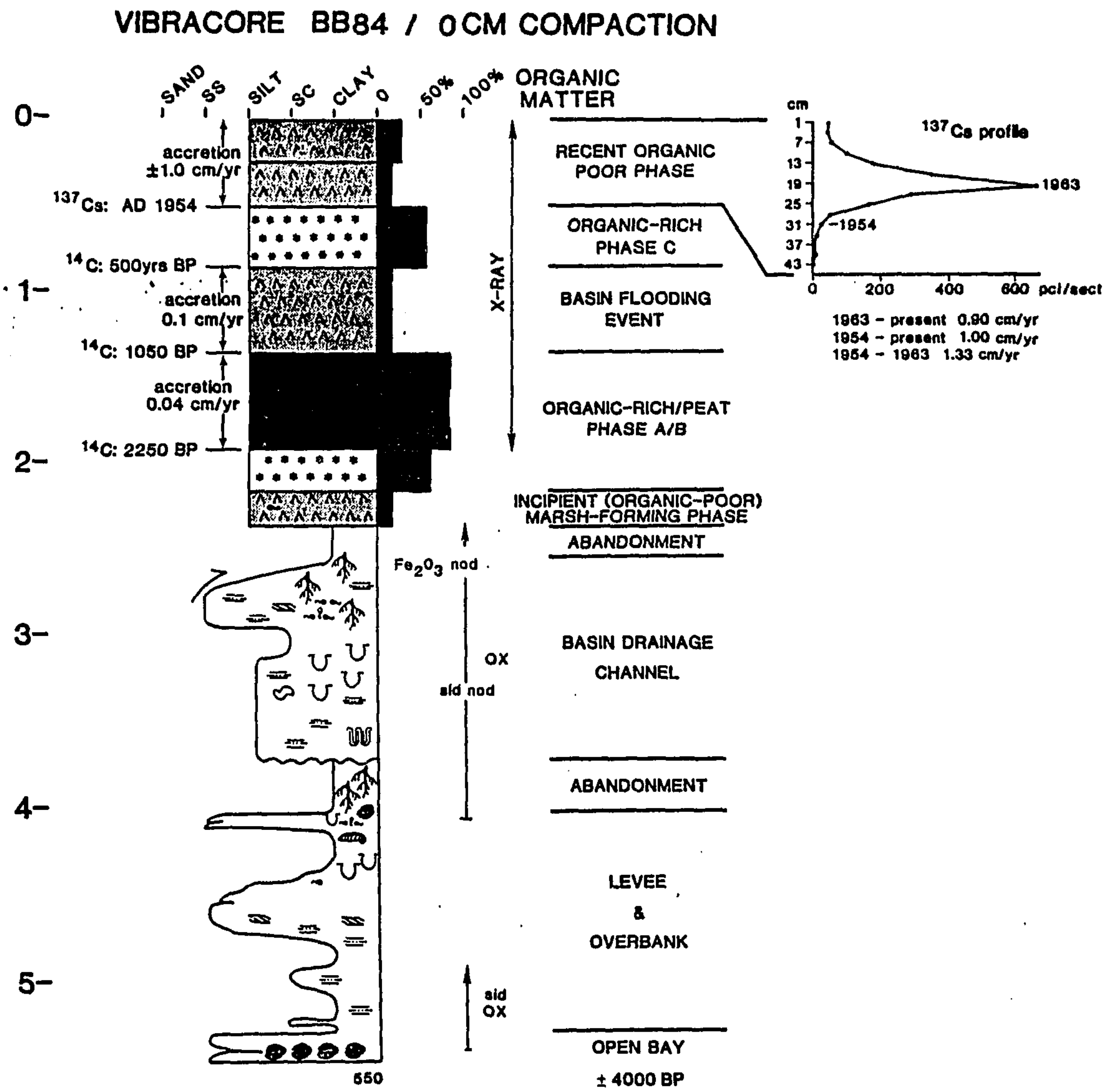


VIBRACORE BB82 / 0CM COMPACTION

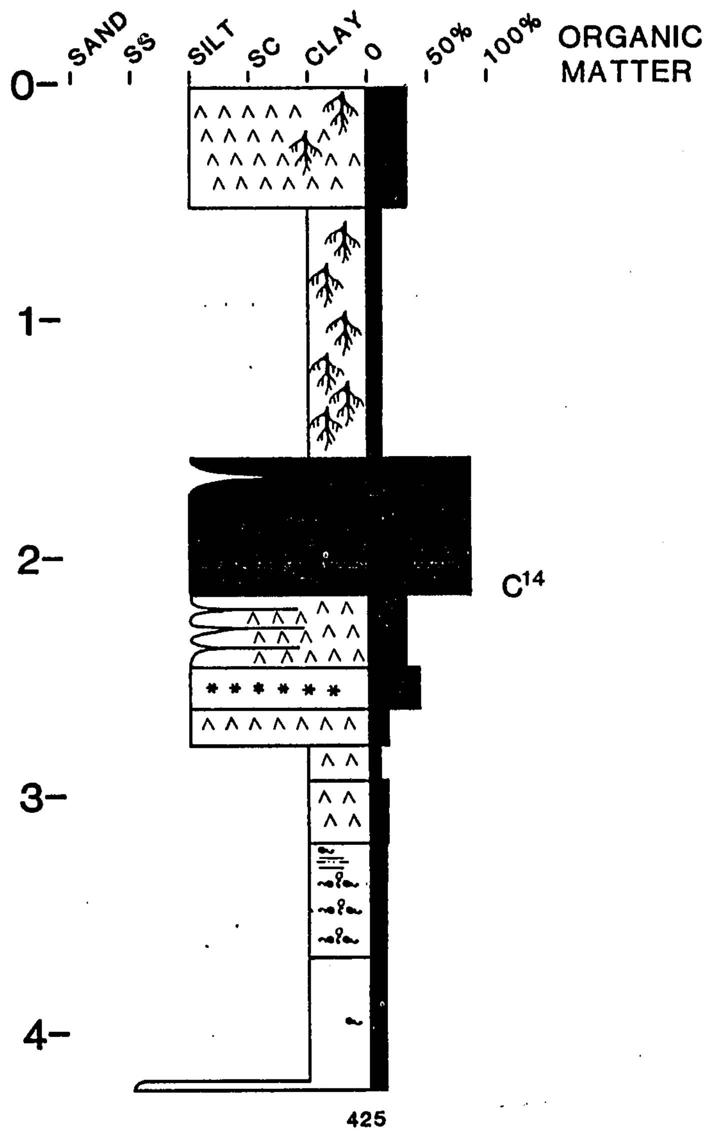


VIBRACORE BB 83 / 30CM COMPACTION

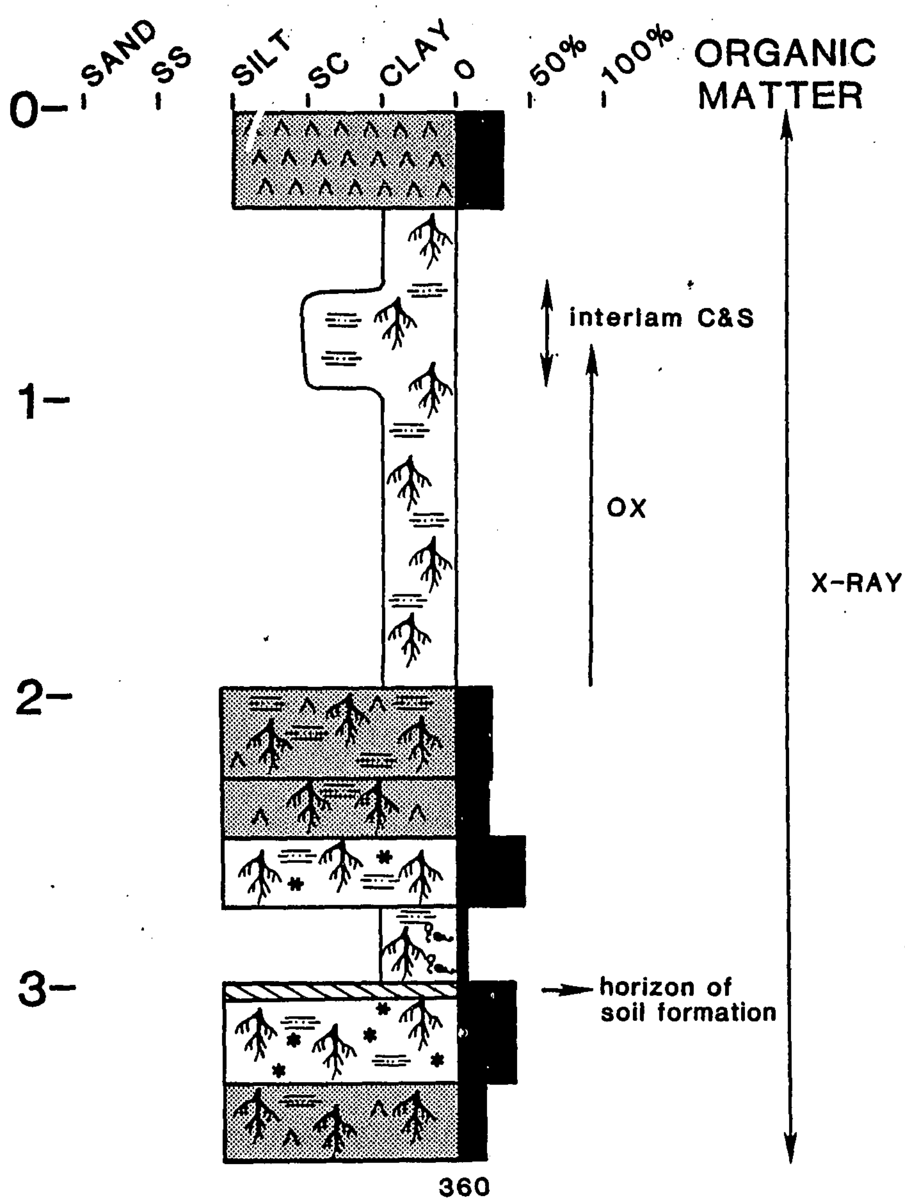



VIBRACORE BB84 / 0CM COMPACTION
SAND SS SILT SC CLAY 0 50% 100% ORGANIC MATTER
0- 1- 2- 3- 4- 5-
accretion ±1.0 cm/yr
137Cs: AD 1954
14C: 500yrs BP
accretion 0.1 cm/yr
14C: 1050 BP
accretion 0.04 cm/yr
14C: 2250 BP
X-RAY
Fe2O3 nod
OX
sid nod
sid OX
550
RECENT ORGANIC POOR PHASE
ORGANIC-RICH PHASE C
BASIN FLOODING EVENT
ORGANIC-RICH/PEAT PHASE A/B
INCIPIENT (ORGANIC-POOR) MARSH-FORMING PHASE
ABANDONMENT
BASIN DRAINAGE CHANNEL
ABANDONMENT
LEVEE & OVERBANK
OPEN BAY ± 4000 BP
cm
1 7 13 19 25 31 37 43
137Cs profile
1963
1954
0 200 400 600 pci/sect
1963 - present 0.90 cm/yr
1954 - present 1.00 cm/yr
1954 - 1963 1.33 cm/yr

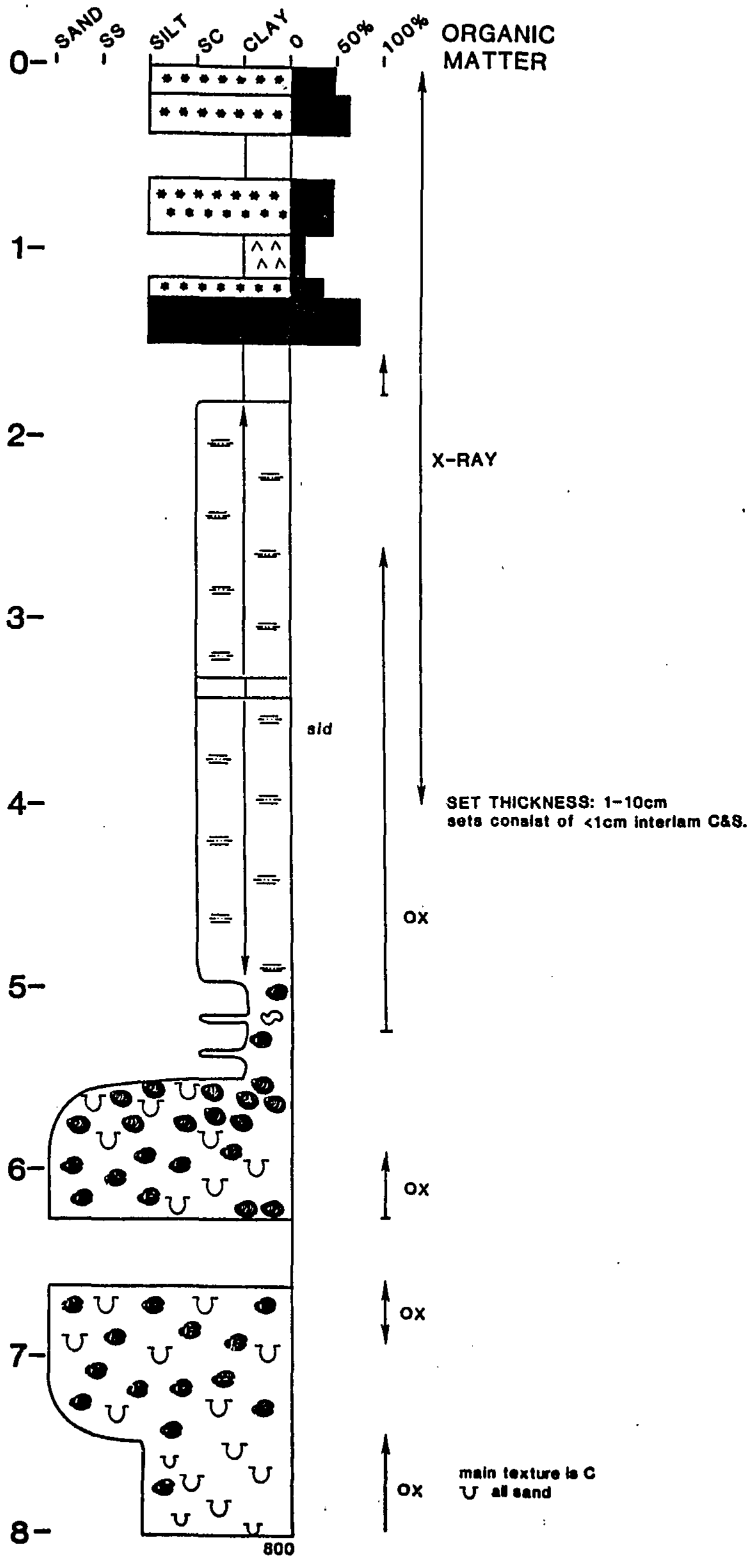
VIBRACORE BB85 / 120CM COMPACTION



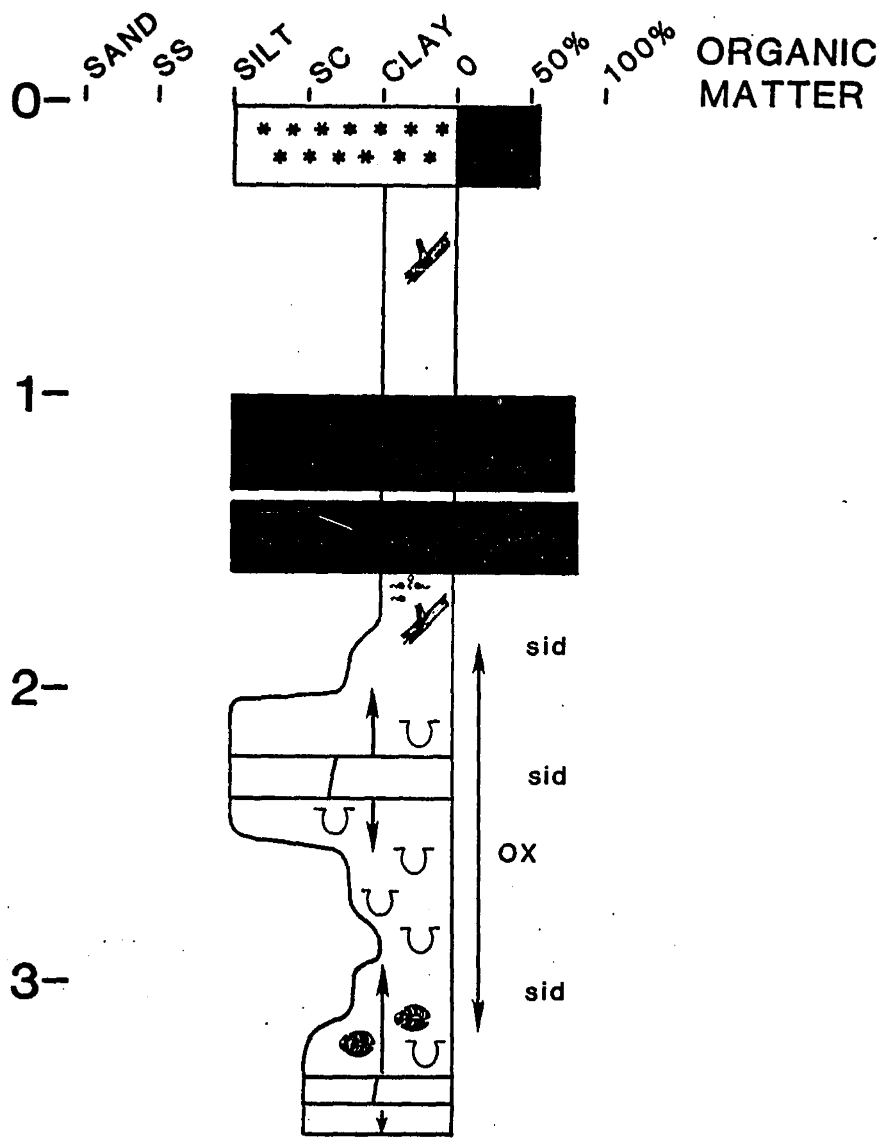
VIBRACORE BB86 / 55CM COMPACTION



VIBRACORE BB87/150CM COMPACTION

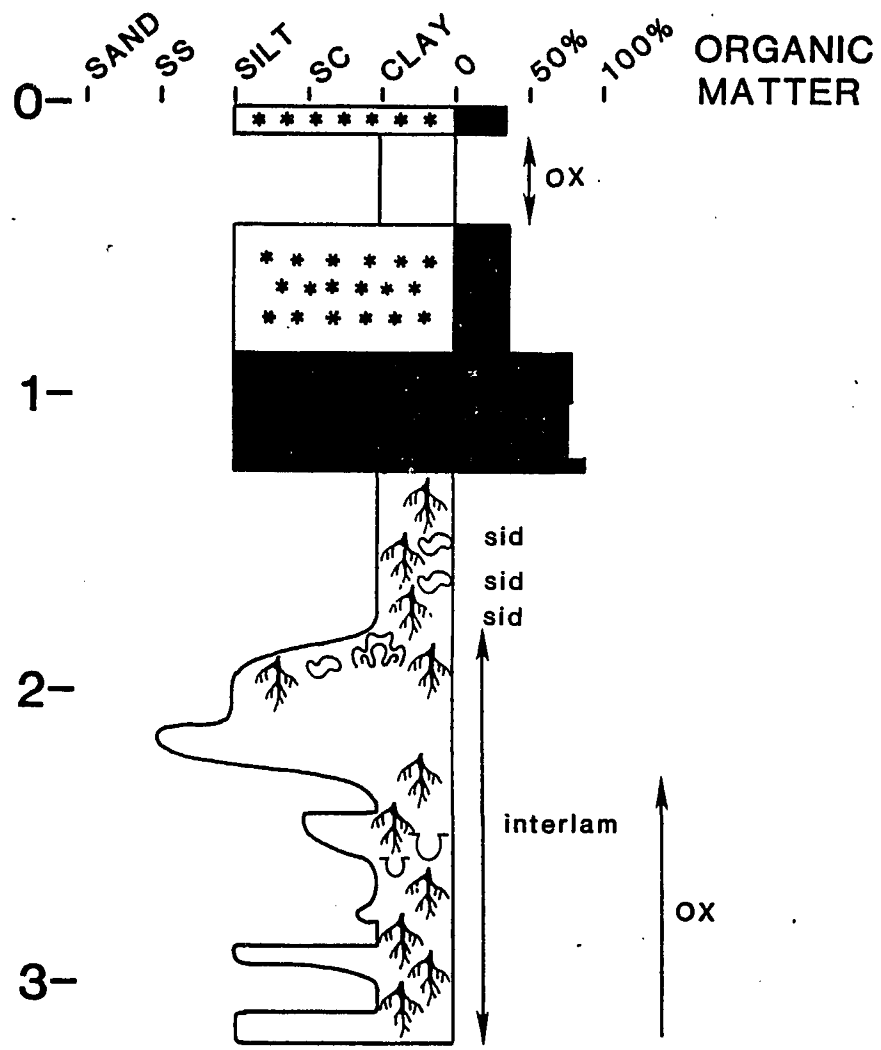


VIBRACORE BB88 / 90CM COMPACTION

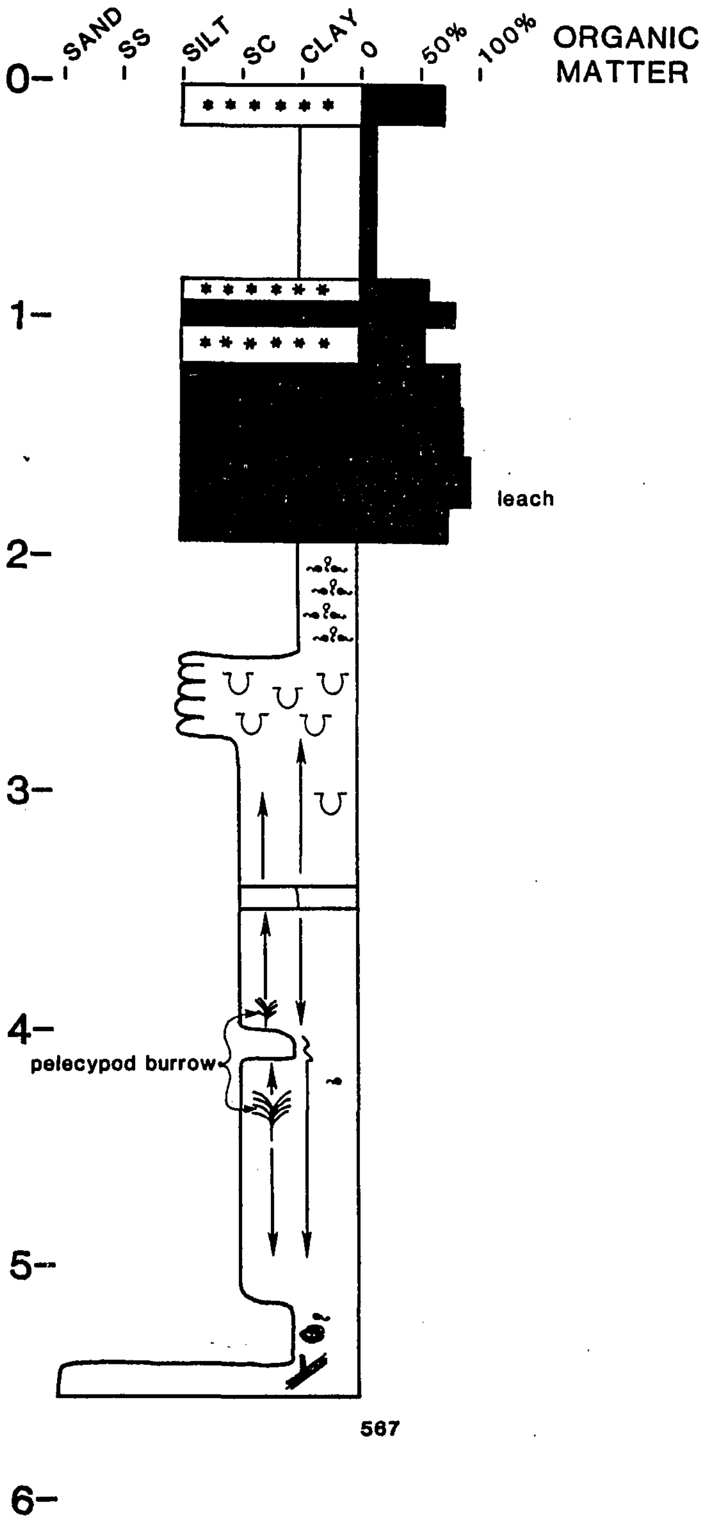


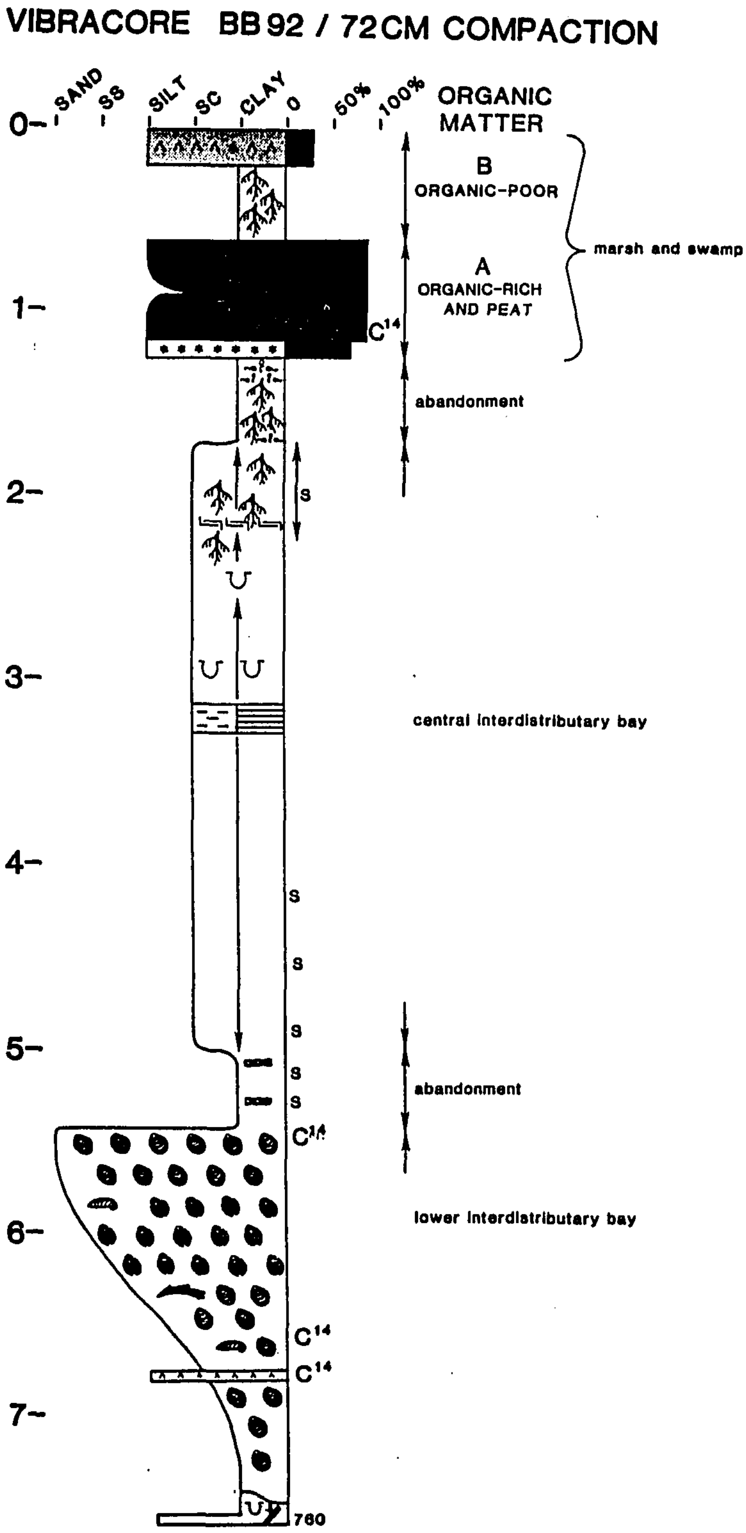
Sediments deformed by coring

VIBRACORE BB89 / 85 CM COMPACTION

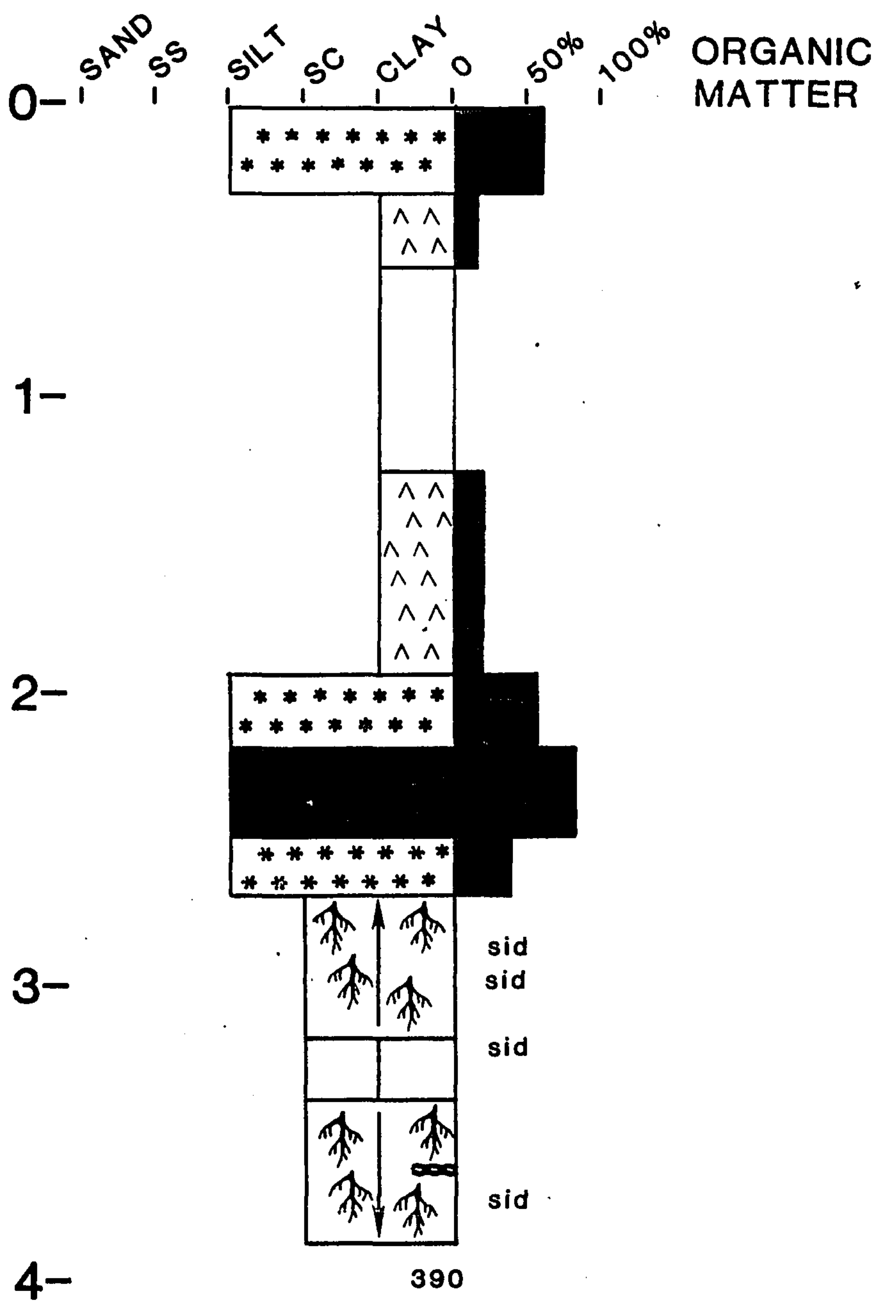


VIBRACORE BB90 / ?CM COMPACTION

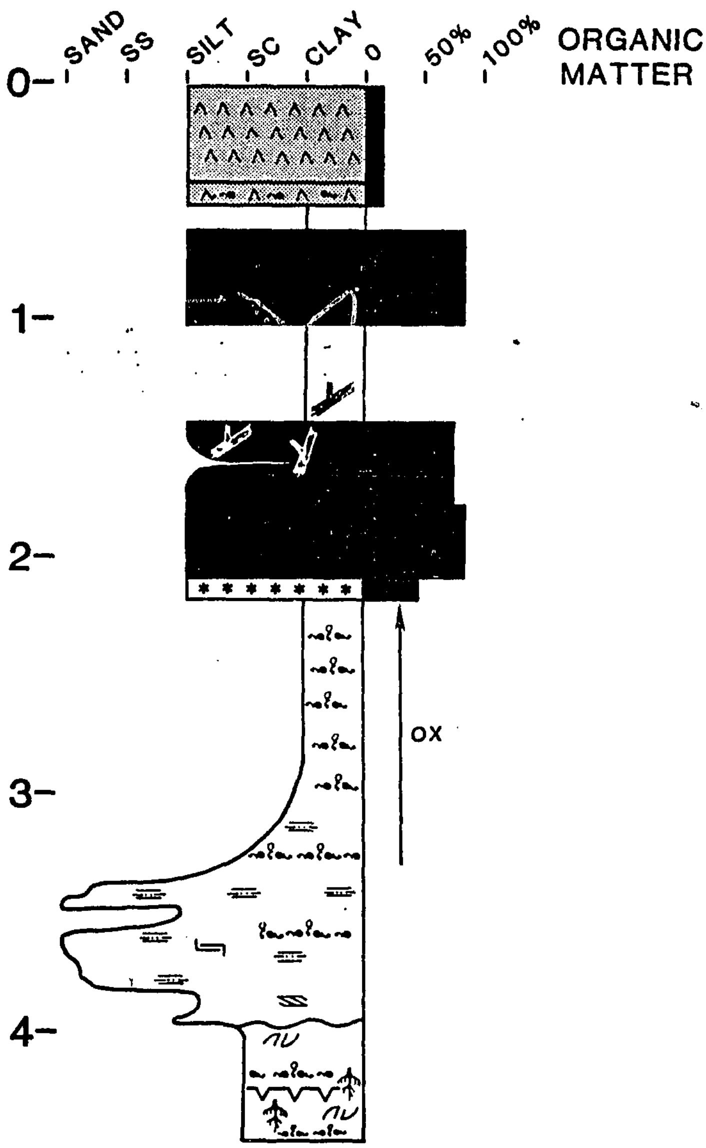



VIBRACORE BB 92 / 72CM COMPACTION
SAND
SS
SILT
SC
CLAY
0
50%
100%
ORGANIC MATTER
0-
1-
2-
3-
4-
5-
6-
7-
B
ORGANIC-POOR
A
ORGANIC-RICH AND PEAT
marsh and swamp
abandonment
central interdistributary bay
abandonment
lower interdistributary bay
C^{14}
s
760

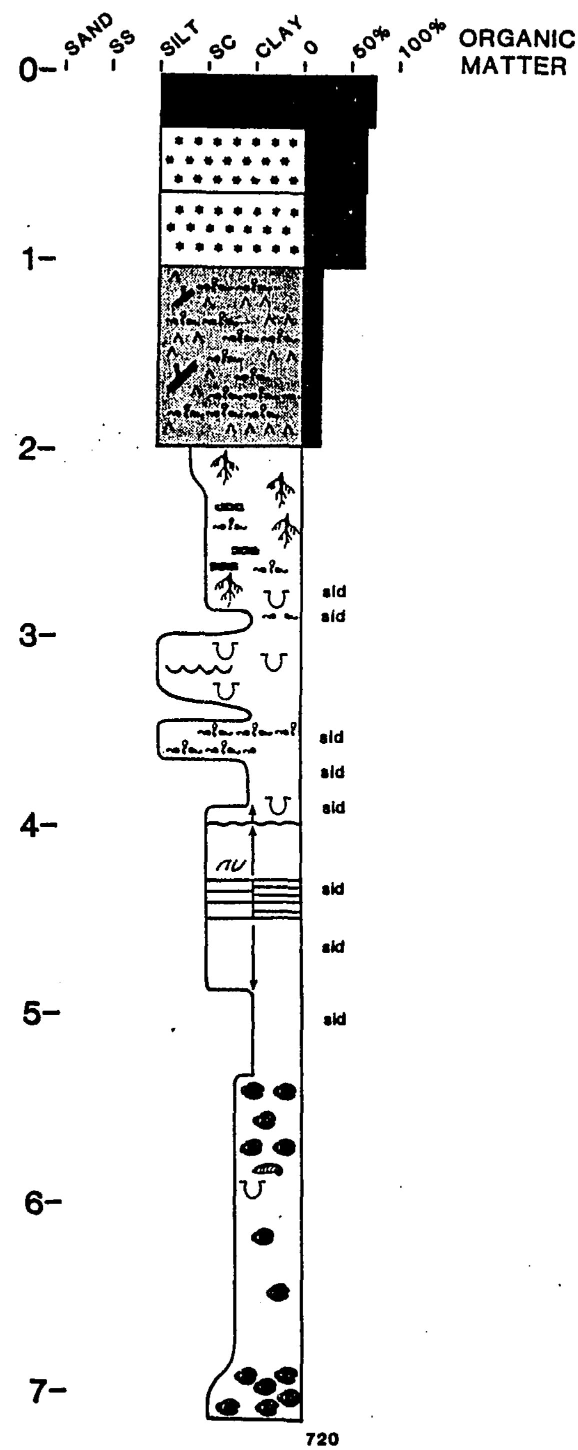
VIBRACORE BB93 / 42CM COMPACTION

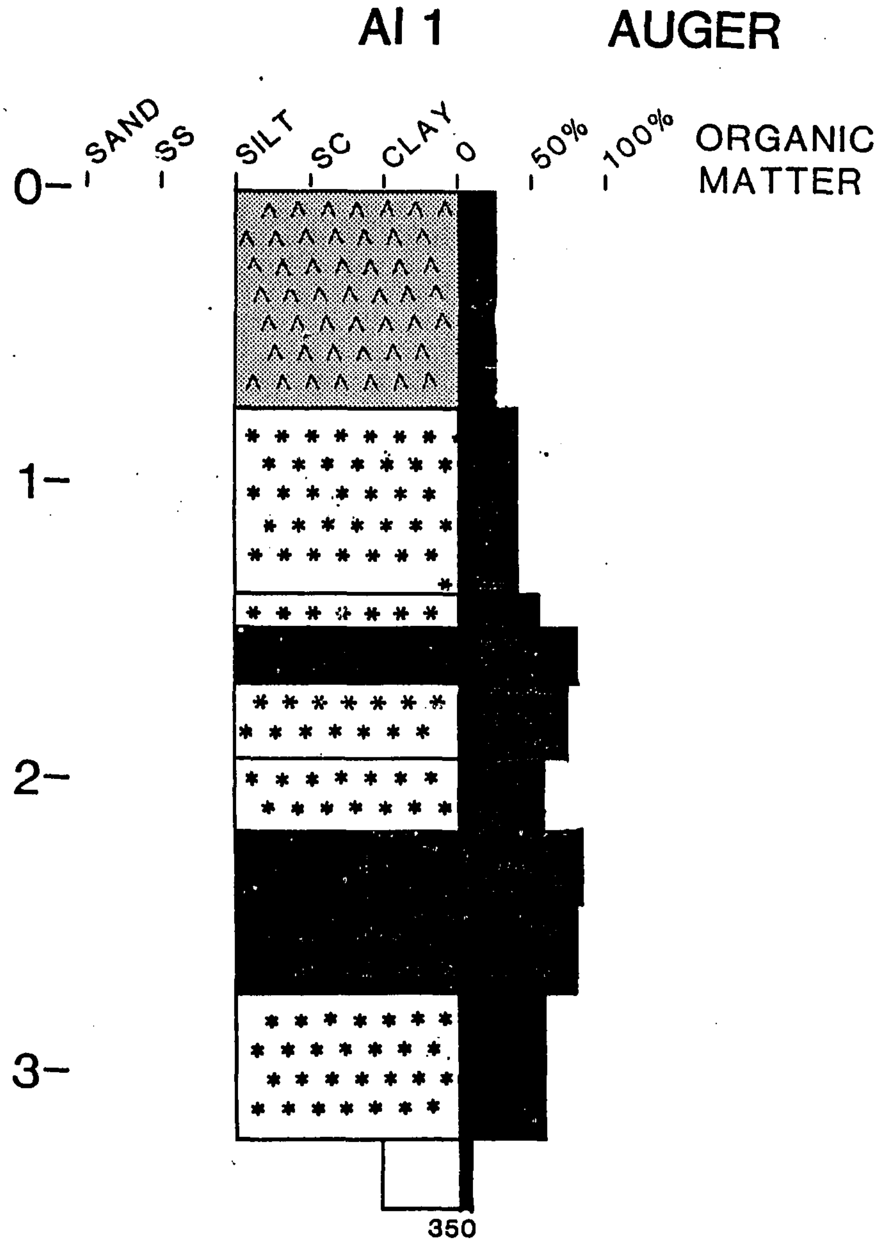


VIBRACORE BB94 / 49CM COMPACTION

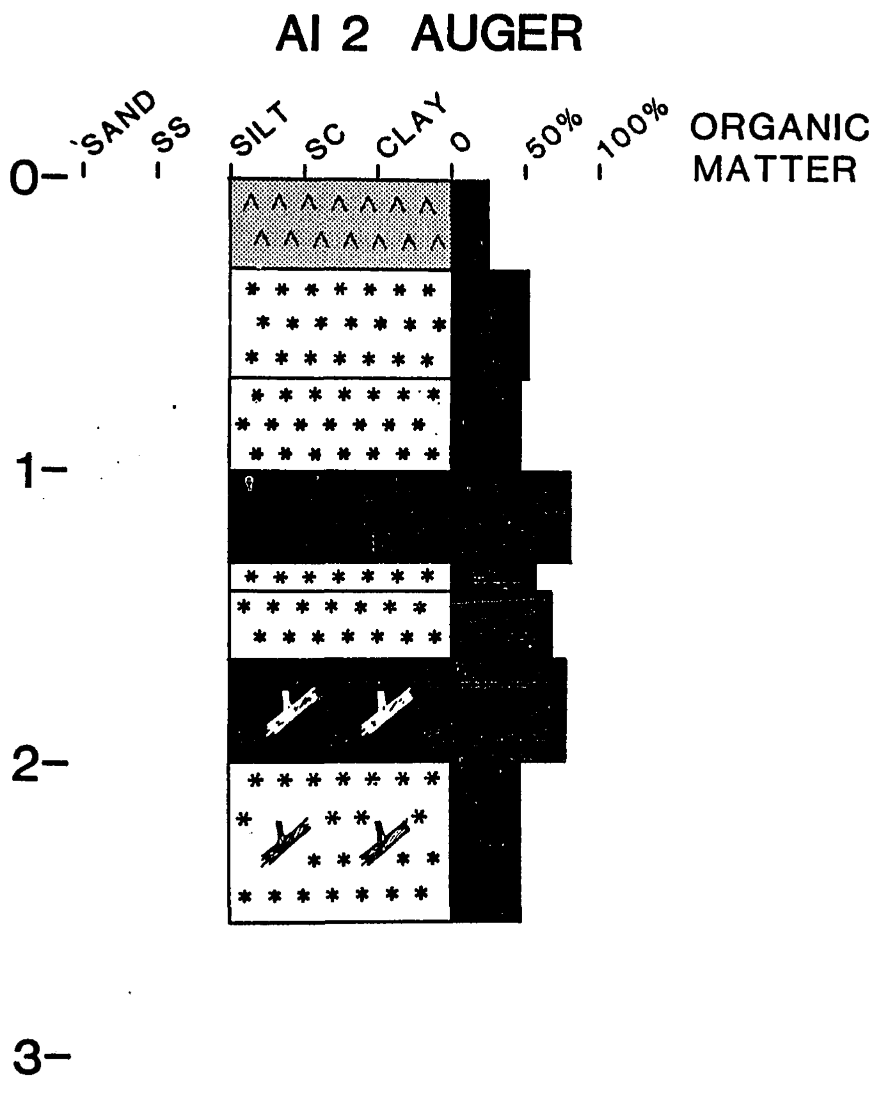


VIBRACORE BB95 / 48CM COMPACTION

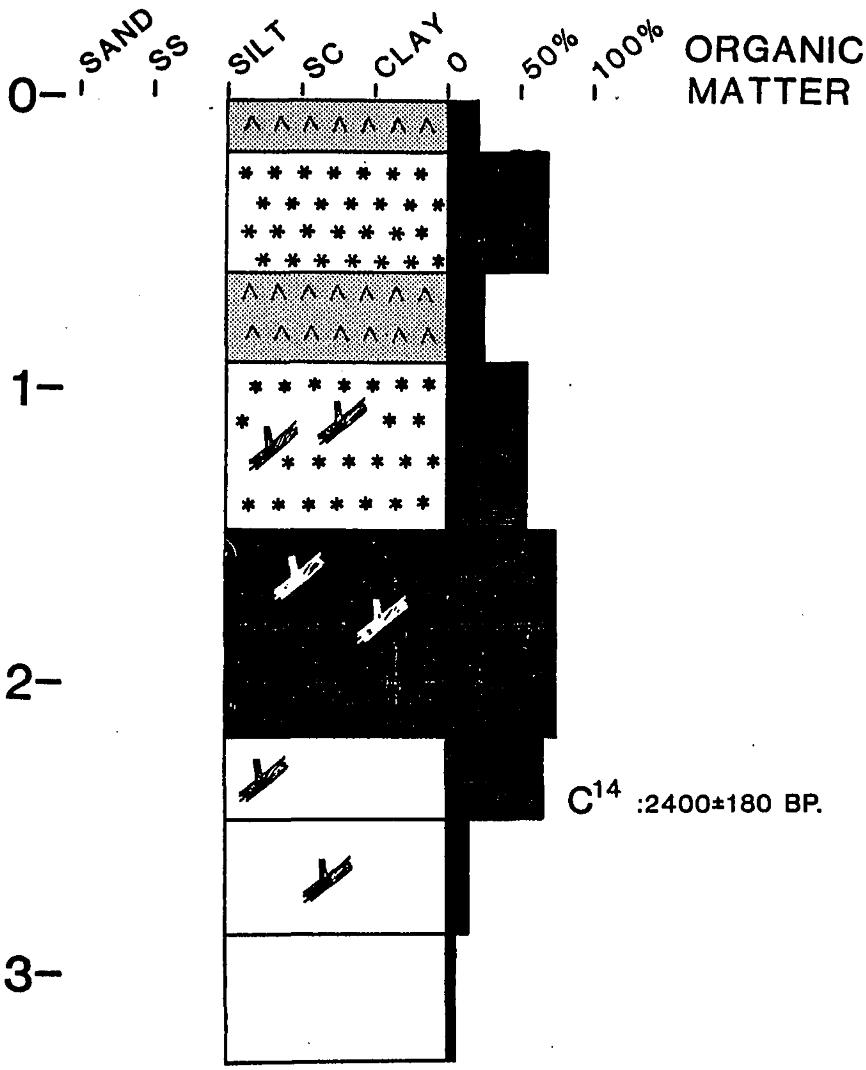




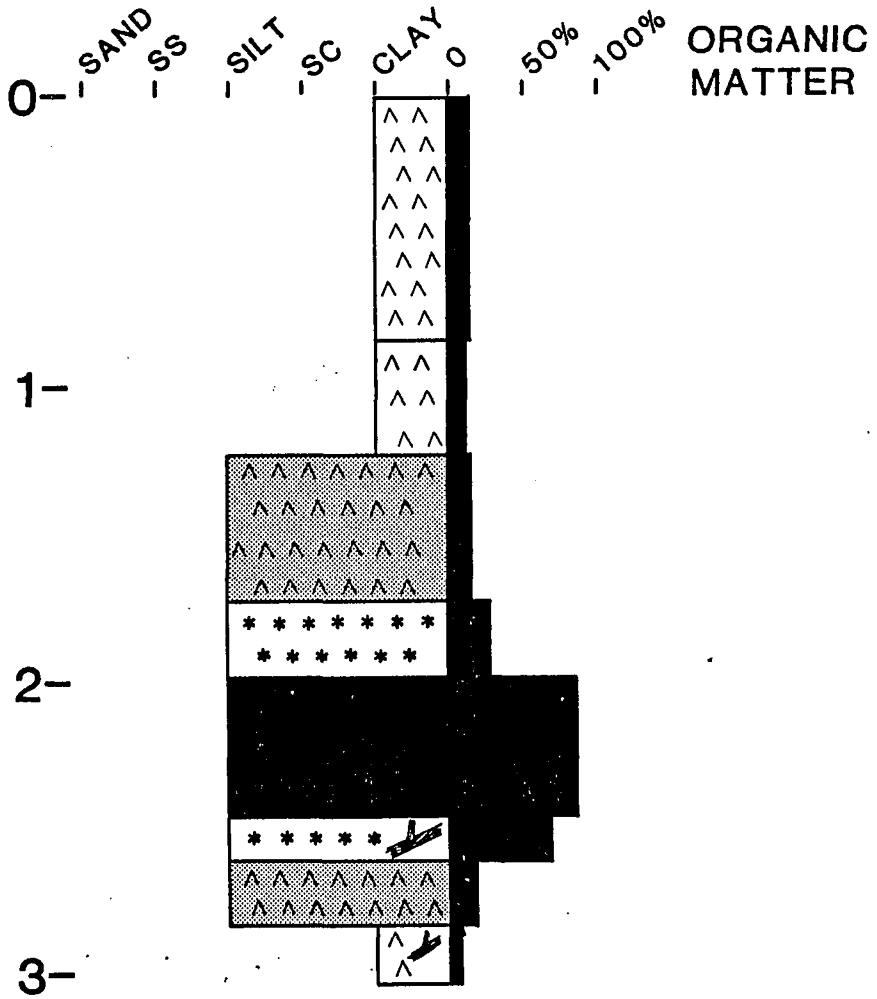
AI 1
AUGER
SAND
SS
SILT
SC
CLAY
0
50%
100%
ORGANIC MATTER
0–
1–
2–
3–
350


AI 2 AUGER
SAND
SS
SILT
SC
CLAY
0
50%
100%
ORGANIC MATTER
0-
1-
2-
3-

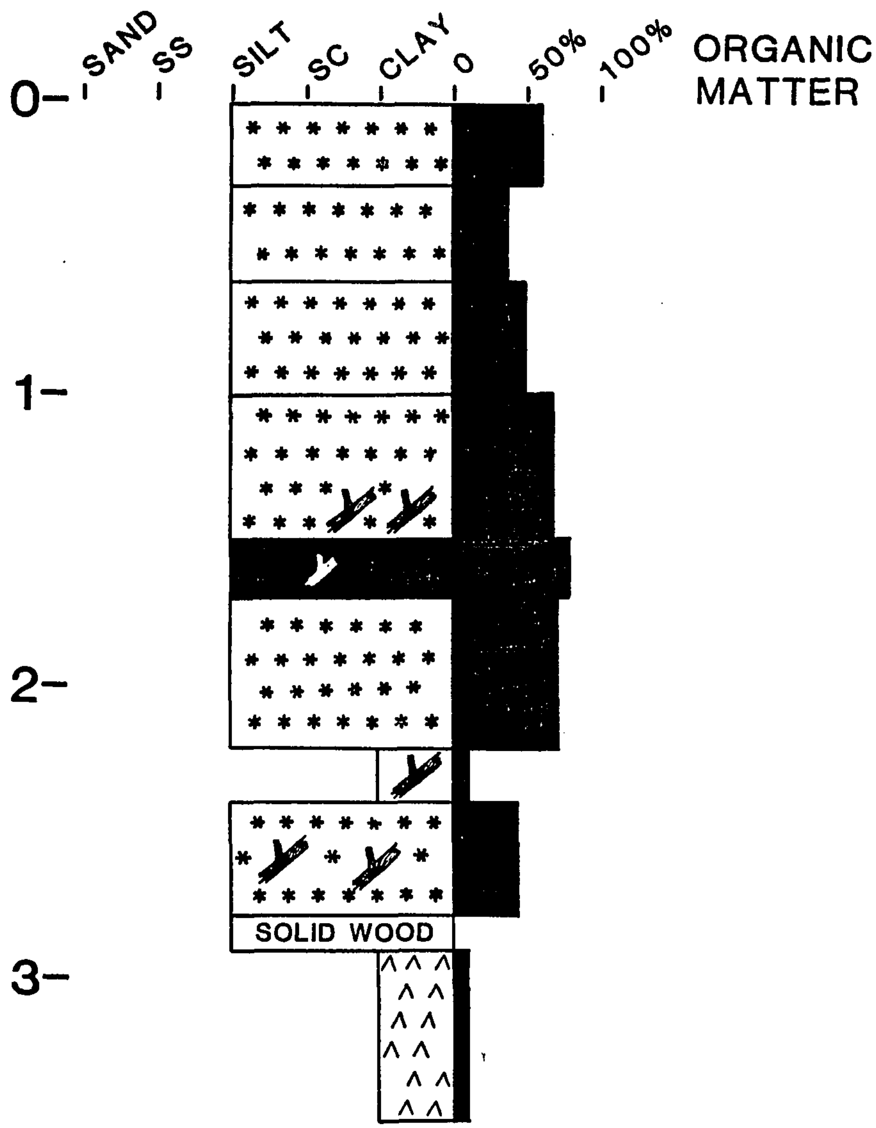
VIBRACORE AI 3 / 73 CM COMPACTION



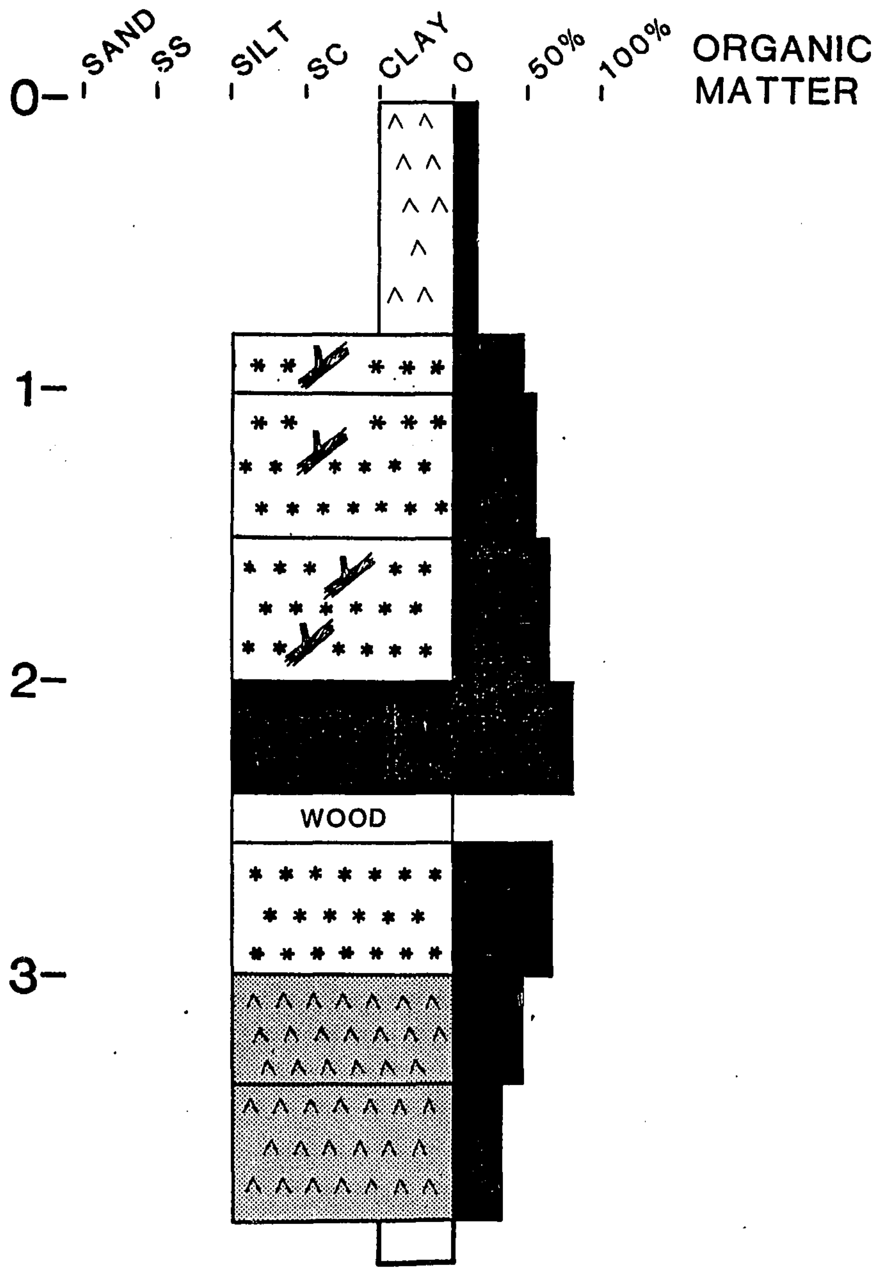
VIBRACORE AI 4 / 33 CM COMPACTION



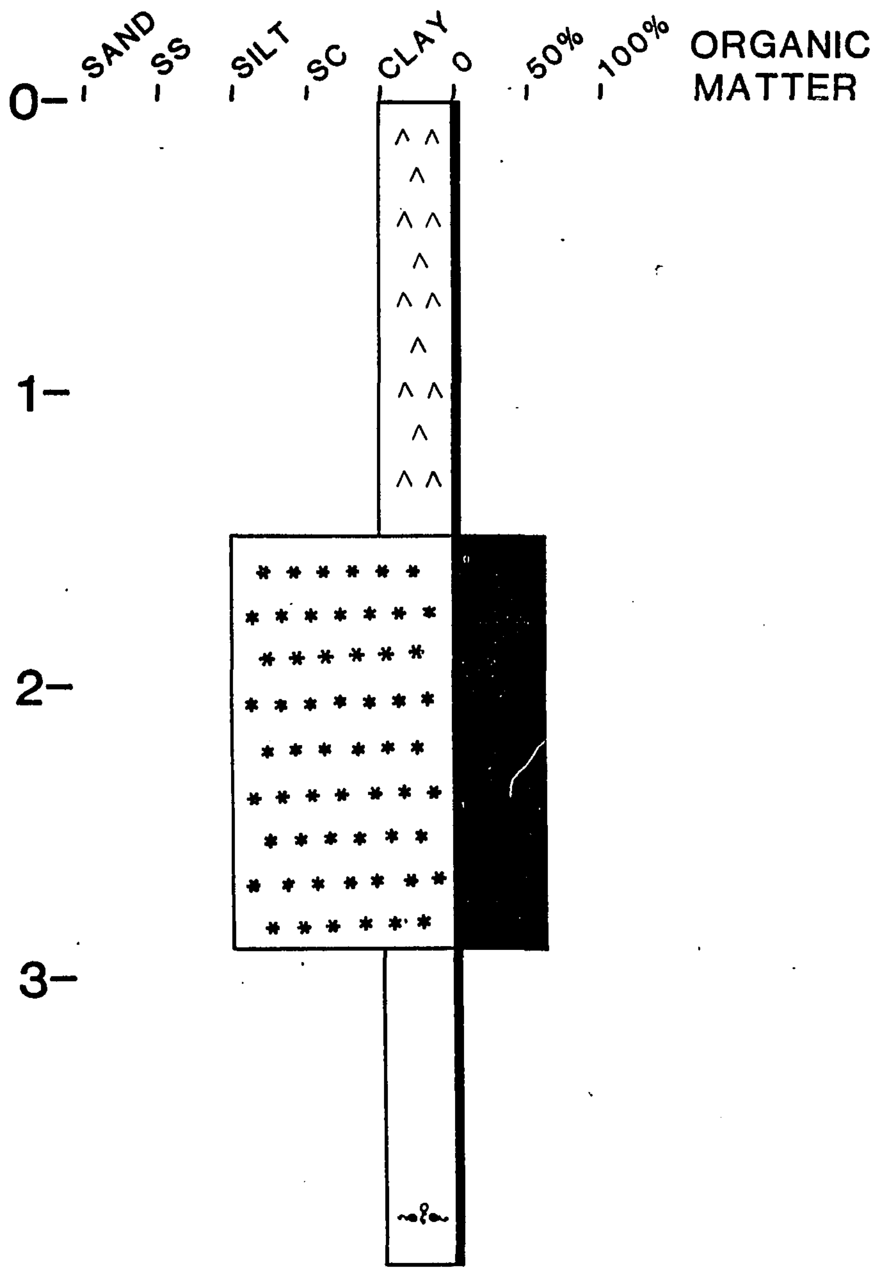
AI 5 / AUGER



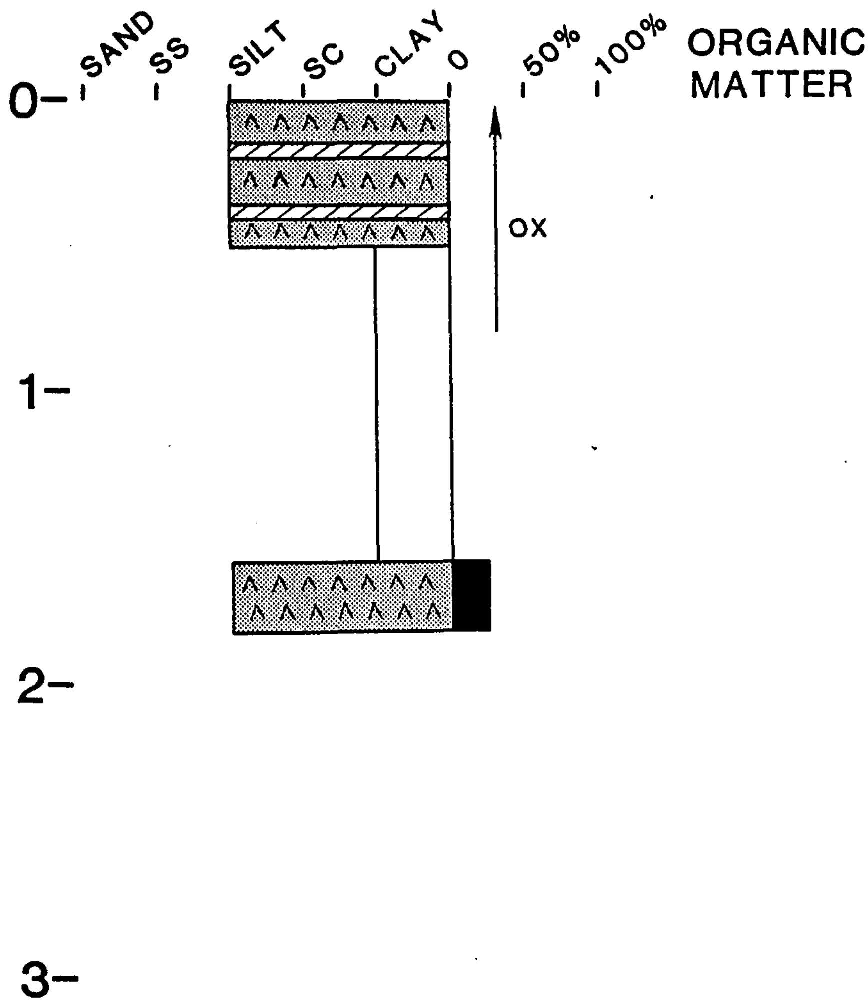
Al 6 AUGER



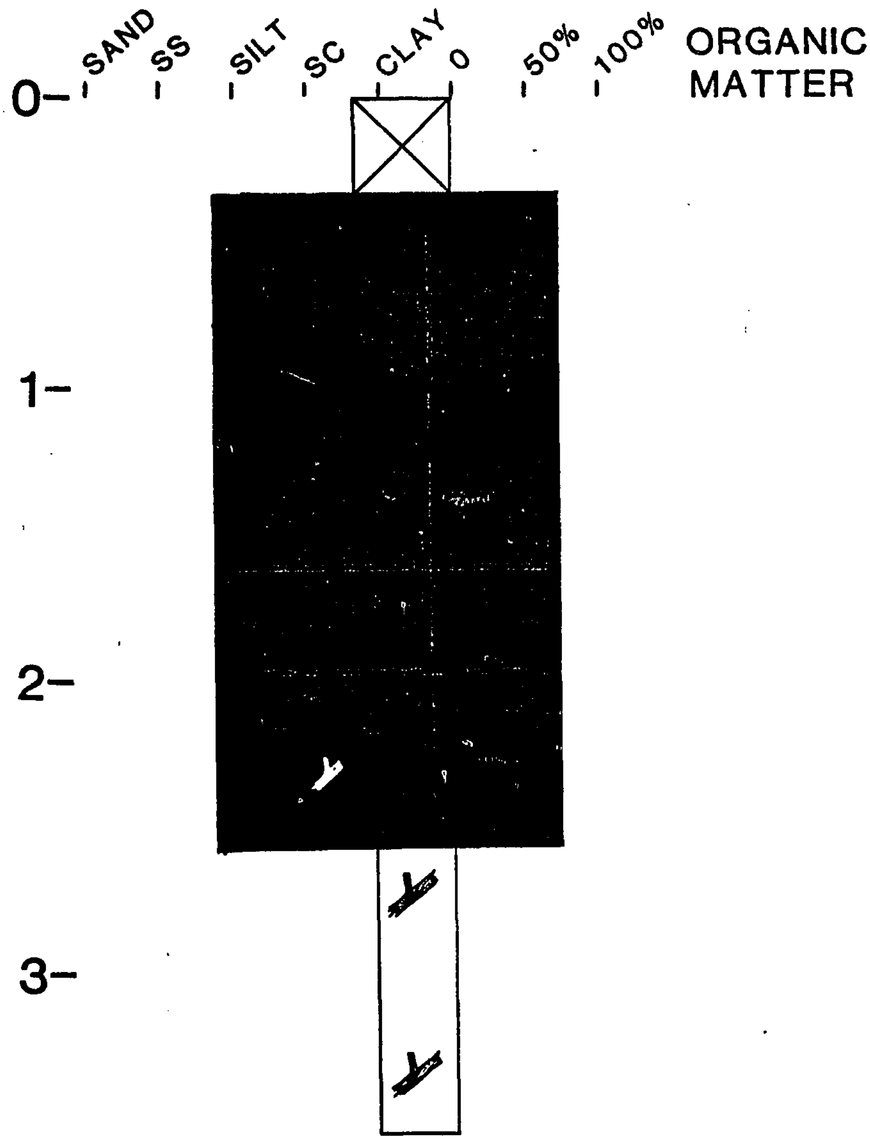
AI 7 / 77 CM COMPACTION



AI 8 / 0 CM COMPACTION



AI 9 / 54CM COMPACTION



VITA

Elisabeth Catharina Kosters was born on November 16, 1952, in Eindhoven, the Netherlands, first child of Andries and Sum Kosters. At age 5, she moved with her family to Baarn, where she attended "Het Baarnsch Lyceum" from 1964-1971 for her high-school education, graduating in the top 10% of her class.

She then went to Groningen where she obtained her Bachelor's degree in geology in the spring of 1975. She subsequently attended the Universities of Amsterdam and Utrecht and the International Institute for Aerial Survey and Earth Sciences (ITC) in Enschede. These combined studies resulted in 1980 in the completion of her MS degree in geomorphology and sedimentology from the University of Amsterdam. In the fall of that year she moved to the United States where she enrolled as a Ph.D. student in the Department of Geology at LSU. In 1981 she became a Research Associate with the Louisiana Geological Survey and in 1984 re-enrolled in the Department of Marine Sciences, while remaining employed with the Geological Survey. In August of 1986, she accepted a position as basin analyst with the Bureau of Economic Geology in Austin, Texas.

In 1983, she married Robert van den Bold. They have a daughter, Mara Gabrielle.

DOCTORAL EXAMINATION AND DISSERTATION REPORT

Candidate: Elisabeth Catharina Kosters

Major Field: Marine Sciences

Title of Dissertation: PARAMETERS OF PEAT FORMATION IN THE MISSISSIPPI DELTA

Approved:

Harry H. Roberts

Major Professor and Chairman

William Boyle

Dean of the Graduate School

EXAMINING COMMITTEE:

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Date of Examination:

July 31, 1986